PIBS #4915e

Deloro Mine Site Cleanup
Mine Area Rehabilitation Alternatives
Final Report

Prepared for:

ONTARIO MINISTRY OF THE ENVIRONMENT

Prepared by:

CH2MHILL

October 2003

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Minister of the Environment

119548AR0501-E042002001KWO

Executive Summary

The Deloro Mine/Refinery Site, located in Eastern Ontario, began operations as a gold mine in the 1860s. Over the next 100 years, site activities also included the smelting and refining of a number of other elements including arsenic, silver, and cobalt. Activities associated with the mining, smelting and refining of metals ceased in the 1950s. These historical activities at the site have resulted in significant environmental impacts to the soil, groundwater, surface water and sediment quality both onsite and offsite.

Abandonment of the site by its owner(s) forced the Ontario Ministry of Environment (MOE) to take control of the property in 1979 and to initiate control measures to limit the environmental impact from the site. Remedial initiatives by the MOE have resulted in reductions of arsenic loadings to the Moira River. Arsenic loading to the Moira River has been reduced by more than 80 percent from an annual average of 52.1 kg/day in 1979 to an annual average of less than 10 kg/day since 1983.

To provide further treatment, and to mitigate any unacceptable impacts on human health and the environment, CH2M HILL Canada Limited (CH2M HILL, formerly CH2M Gore & Storrie Limited [CG&S]) was retained by the MOE to develop and implement a comprehensive rehabilitation program focusing on four individual areas of concern at the Deloro Mine Site. These areas included the Mine Area, the Industrial Area, the Tailings Area and the Young's Creek Area. The purpose of this report is to identify and evaluate remediation alternatives for the Mine Area (Main Mine and Remote Mine Areas) and to select a recommended alternative based on the evaluation.

The mining at Deloro was originally centred on the Gatling and Tuttle Shaft Area of the site. This section was the location of a prominent quartz veining system along a regional structural feature. By today's standards the mine shafts in this area were all fairly limited in size, with small volumes of waste rock produced. Waste rock was dumped in the general vicinity of the mine shafts and is readily identifiable. Ore processing occurred in the Gatling and Tuttle Shaft Area; however, none is thought to have been carried out at the Hawkeye, 5 Acres, Pearce, or Cook's Shaft areas. Limited quantities of waste rock are also associated with the former Hawkeye, 5 Acres, Pearce, and Cook's Shaft areas. All other onsite mine workings appear to have been exploratory trenches and adits with minimal waste rock production.

Based on historical research carried out by Commonwealth Historic Research Management Limited (1988), the ore processing was contained to the area to the west of the Red Shaft, located in the areas designated in this report as the Historic Laboratory Area and the Historic Cyanide Mill Area, and in the central Industrial Area to the south. No other parts of the Mine Area are known to have been used for the processing of ores or for metallurgical research.

The identified wastes in the Main Mine Area are waste rock, incidental waste deposits, and heavily impacted soils that are present on the ground surface and the shallow subsurface. Water quality impacts to the Moira River in this area include groundwater discharge from the Tuttle Shaft, and surface runoff from the contaminated waste rock, soils and concentrated mine wastes. In the Remote Mine Area, waste rock contains high arsenic levels. However, the impacts to water quality associated with these remote waste rock areas are considered to be insignificant relative to those occurring at the Gatling and Tuttle Shaft Area. Shallow soils containing arsenic and other constituents above the MOE cleanup guideline for potable groundwater conditions can create an unacceptable impact and require management.

The evaluation of remediation alternatives was conducted in three stages. The first stage involved the screening of conceptual remediation methods and was designed to identify, early in the evaluation process, the most promising methods for site remediation. In the second stage, comprehensive remediation alternatives were developed by combining the primary remediation methods that satisfied the first screening process with enhancing environmental protection features. Finally, in the third stage, the comprehensive remediation alternatives were compared to detailed evaluation criteria reflecting technical, cost, natural environment and social considerations. The comprehensive remediation alternative that was judged to be the most effective and efficient means for remediating the Mine Area was then recommended.

The first step in the generation of remediation alternatives was the development of conceptual remediation methods. The conceptual remediation methods that were identified for the Mine Area are as follows:

TABLE E.1
REMEDIAL METHODS IDENTIFIED FOR MINE AREA

Component of Mine Area	Location of Issue/Problem Within Area	Specific Problem (Designation)	Identified Methods
1. Main Mine Area	Gatling/Tuttle Shafts/Red Shaft/Power House	Waste Rock (Main Mine Waste Rock)	1. Do nothing 2. Cover geofabric, clay, topsoil, and then vegetate 3. Excavate, consolidate, and cover with geofabric, clay, topsoil, and then vegetate, restore excavated areas 4. Excavate and bury in existing mine shafts, restore excavated areas
		Heavily Impacted Soil/ Concentrated Wastes (Main Mine Soils)	1. Do nothing 2. Cover entire affected area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 3. Cover only heavily impacted areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 4. Excavate and dispose of heavily impacted soil, restore excavated areas 5. Excavate and bury in existing mine shafts, restore excavated areas
		Groundwater Discharge from mine workings (Main Mine Groundwater)	1. Do nothing 2. Increase pumping from Tuttle Shaft

TABLE E.1
REMEDIAL METHODS IDENTIFIED FOR MINE AREA

Component of Mine Area	Location of Issue/Problem Within Area	Specific Problem (Designation)	Identified Methods
2. Remote Mine Area	Former Mine Shafts – Hawkeye, 5 Acres, Pearce, Cook's	Waste Rock (Remote Mine Waste Rock)	1. Do nothing 2. Cover with geofabric, clay, topsoil, and then vegetate 3. Excavate, consolidate, and cover with geofabric, clay, topsoil, and then vegetate, restore excavated areas 4. Excavate and bury in existing mine shafts, restore excavated areas
	Undeveloped Areas	Shallow arsenic impacted soils (Remote Mine Soils)	1. Do nothing 2. Excavate and remove for disposal, restore excavated areas 3. Cover with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 4. Excavate and bury in existing mine shafts, restore excavated areas

These methods were then screened to eliminate alternatives that would not be effective, would not comply with regulatory requirements, or that could not satisfy the design closure criteria for the site. Based on the results of the screening, the methods that were not rejected were either classified as primary remediation methods or enhancing protective features. Primary remediation methods are methods that have the ability to significantly reduce contaminant loading to the environment. Methods that cannot reduce contaminant loads alone can be combined with the primary remediation alternatives to provide additional protection. The combination of primary remediation methods and enhancing protective features forms the comprehensive remediation alternatives.

The comprehensive remediation alternatives were screened a second time using the exclusionary criteria. This step was completed to ensure that the addition of an enhancing protective feature to a primary remediation method did not undermine that method's ability to mitigate risks to human health and the environment. The following three comprehensive remediation alternatives satisfied the screening criteria a second time:

- **Main Mine Area:** *Increase pumping from Tuttle Shaft; cover entire affected soil/concentrated waste area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate (this includes covering waste rock in the same manner minus the armour rock)*

  Remote Mine Area: *Cover waste rock with geofabric, clay, topsoil, and then vegetate*

- **Main Mine Area:** *Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; cover only heavily impacted soil/concentrated waste areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate*

  Remote Mine Area: *Cover waste rock with geofabric, clay, topsoil, and then vegetate*

- **Main Mine Area:** *Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; excavate and dispose of heavily impacted soils, cover excavated area with clay, topsoil, and then vegetate*

Remote Mine Area: *Cover waste rock with geofabric, clay, topsoil, and then vegetate*

The detailed evaluation resulted in the following comprehensive remediation alternative being recommended for the Mine Area:

- **Main Mine Area:** *Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; cover only heavily impacted soil/concentrated waste areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate*

  Remote Mine Area: *Cover waste rock with geofabric, clay, topsoil, and then vegetate*

The recommended remediation alternative was based on increased pumping from the Tuttle Shaft, covering the waste rock areas, excavation of some highly contaminated materials, and capping of the less contaminated materials.

Application of a risk assessment was identified as the most appropriate approach for the undeveloped parts of the Remote Mine Area and is common to all alternatives considered.

Operating, maintenance and monitoring efforts under the recommended alternative will be associated primarily with the Tuttle Shaft pumping system, vegetated cover maintenance and monitoring the water quality of the Moira River upstream and downstream of the Mine Area. A detailed operations and maintenance plan should be established for the Mine Area following implementation of the recommended alternative.

Data gaps and issues that should be resolved prior to final design and implementation of the recommended alternative include the following:

- A large pool in the Moira River, located immediately to the east of the Tuttle Shaft, was identified as a potential sediment trap which could be acting as an arsenic source for this section of the river (SRK, 1998). To assess the concentration of metals in the substrate of the pool as well as upstream and downstream of the Tuttle Shaft, CH2M HILL collected bottom sediment samples in August 1998. All results of the sediment sampling program are discussed in a report entitled *Technical Memorandum - Moira River Sediment Survey* (CH2M HILL, March 2001).

  The findings of the above work are preliminary. A much more extensive study of sediments downstream of Deloro was completed in the Moira River Study (Golder, 2001). This study concluded that, although present, the contaminated sediments did not appear to indicate an adverse impact. The significance of contaminated sediment in the Moira River at the Deloro site will be re-examined as part of an ecological risk assessment.

- Confirmation of material availability and associated costs must be made for optimizing the design. This could include limiting the use of high-quality clay and the use of more low-cost materials.

The costs associated with the recommended alternative include a capital cost of $660,000 and an annual operation and maintenance cost of $10,500. The net present value of the recommended alternative assuming an effective interest rate of 5 percent and a planning horizon of 20 years is $800,000. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

The recommended alternative will be further developed in a subsequent report entitled *Deloro Mine Site Cleanup – Closure Plan for the Mine Area*. The Closure Plan will be the subject of additional public consultation and stakeholder review in addition to providing supporting documentation for regulatory reviews and applications. The comments will be incorporated into the final rehabilitation strategy and implemented in the construction phase of the project.

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1. Introduction

1.1 Background

Nearly a century of mining and industrial activity has resulted in significant environmental degradation of the Deloro Mine/Refinery site. Tailings and waste zones at the site contain up to 30 percent arsenic. Runoff and seepage from the various waste zones at the site have resulted in arsenic contamination of the Moira River, which flows through the site. Abandonment of this site by its owner(s) forced the Ontario Ministry of the Environment (MOE) to take custody of the property in 1979 and to initiate control measures to limit the environmental impact from the site.

CH2M HILL Canada Limited (CH2M HILL, formerly CH2M Gore & Storrie Limited [CG&S]) was retained by the MOE in April 1997 to develop and implement a comprehensive rehabilitation program for the closure of this former mine site. As part of this comprehensive rehabilitation program, CH2M HILL is developing remediation alternative plans for each of the four areas within the mine site's footprint, as shown in Figure 1-1. The limits of these four areas have been developed based on historical land use and waste disposal practices. The four areas include:

- The Industrial Area, where smelting and refining of the various ores were carried out
- The Tailings Area, where the by-products of the production phase were stored
- The Mine Areas, on both the east and west sides of the Moira River
- The Young's Creek Area, which has been impacted from historical releases from the Tailings Area

Closure plans will be developed for each of these four areas based on the closure objectives identified for the site in the report entitled *Deloro Mine Rehabilitation Project, Development of Closure Criteria, Final Report* (CG&S, October 1998a) and the recommended rehabilitation alternatives developed for each area in the following reports:

- *Deloro Mine Site Cleanup – Industrial Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Tailings Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Mine Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Young's Creek Area Rehabilitation Alternatives*

1.2 Purpose of this Report

The overall objective of the Deloro Mine Site Cleanup is to successfully rehabilitate the mine site to mitigate, within reason, any unacceptable impacts on human health or the environment. As part of this overall objective, several area-specific objectives have been developed. Achieving these objectives, in conjunction with the other area-specific objectives, will aid in the successful rehabilitation of the Deloro Mine Site.

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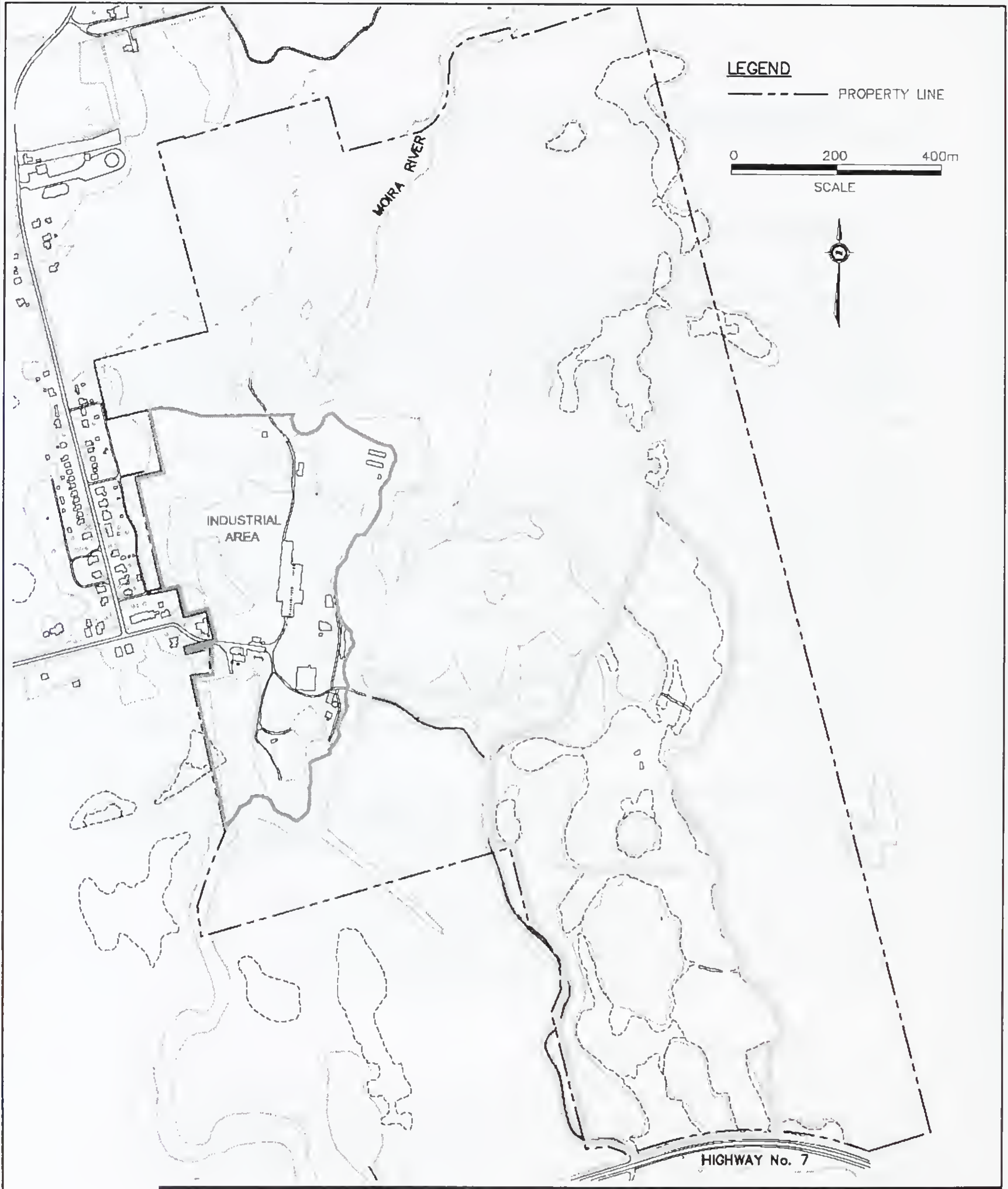

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FIGURE 1-1
DELORO MINE/REFINERY SITE SHOWING THE MINE, INDUSTRIAL, TAILINGS AND YOUNG'S CREEK AREAS
DELORO, ONTARIO

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The alternatives reports summarize the previous investigations and reports that have been commissioned for the subject areas. Several alternatives that have been identified in previous reports are evaluated based on their environmental impacts. The criteria used to evaluate the impacts of alternatives reflect all components of the environment, including natural and social environmental impacts, as well as technical and cost considerations. The evaluation approach also recognizes the need to determine and assess "reasonable" remedial alternatives based on existing site information. The identification of remediation alternatives is not intended to be an exhaustive search for all conceivable or experimental remediation solutions that could be attempted. The recommended alternative for each of the four areas will meet the closure criteria established in the report entitled *Deloro Mine Rehabilitation Project, Development of Closure Criteria, Final Report* (CG&S, October 1998a) and will be further developed in subsequent reports outlining closure plans for each of the areas.

Considerable previous work has been completed at the site, specifically in the Mine Area, to address safety concerns and to achieve closure of underground mine workings (MOEE, 1995; Dupont, 1994). The alternatives described in this report augment earlier efforts and focus on surficial or rehabilitation of near surface mine wastes and by-products of mining/metallurgical processing. This report should be read in conjunction with earlier reports on this topic (MOEE, 1995; Dupont, 1994).

1.3 Organization of Report

This report consists of seven sections, including the introduction. Section 2, Background and Problem Definition, describes the history of the site and a brief summary of the results of previous site investigations and studies within the subject area. The existing physical conditions of the subject area including additional background details and the nature and volume of the heavily impacted material are described in Section 3. Section 4, Alternatives Evaluation Process, describes the process by which alternatives are generated and the approach to evaluation of the alternatives, as well as the closure objectives that must be met by the rehabilitation alternatives. Additional information pertaining to the detailed evaluation criteria is contained in Appendix A. Section 5, Development and Evaluation of Alternatives, establishes, describes and evaluates rehabilitation methods and alternatives. Section 6 provides the recommended remedial alternatives and cost opinion and identifies any data gaps that should be filled. Details associated with the opinion of cost information are contained in Appendix B. Section 7 lists the references used in the preparation of this report.

2. Background and Problem Definition

This section provides a brief description of the history of the Deloro Mine Site and the Mine Area. It also clearly defines the problems to be mitigated as part of the recommended remediation alternative. A detailed description of the historical mining activities that have taken place at the Deloro Mine Site since the early 1860s is provided in the report entitled *An Historical Analysis of the Deloro Site* (Commonwealth Historic Resource Management Limited, January 1988).

2.1 Deloro Mine Site

The Deloro site is located in Eastern Ontario along the banks of the Moira River on the eastern boundary of the Village of Deloro (see Figure 2-1, Deloro Mine Site Location). The Mine Area which consists of land on both the west and east sides of the Moira River (i.e. Main Mine Area and Remote Mine Areas) is approximately 117 ha in area. The entire property, which includes the Industrial Area, Tailings Area, Mine Area and the on-site portion of Young's Creek, is approximately 202 ha in area. The general boundaries of the Mine Area are shown in Figure 1-1 in Section 1 and include the Main Mine Area and the Northwest, Northeast, South and East Remote Mine Areas.

Access to the mine site is via Deloro Road, which is accessed from Highway 7 approximately 4 km east of Marmora. The principal population centres in the area are the Village of Deloro (pop. 180) and the Villages of Marmora (pop. 1,700) and Madoc (pop. 1,400), located approximately 5 km southwest and 10 km east of the mine site, respectively.

The Deloro site began operation as a gold mine in the 1860s and evolved over the next century to mine and refine gold, as well as smelting and refining of a number of other elements including arsenic, silver and cobalt. It was the first plant in the world to produce cobalt commercially and was also a leading producer of stellite, a cobalt-chromium-tungsten alloy. Concentrates from uranium extraction were imported to the site and further processed to extract cobalt. Arsenic-based pesticides were produced from the by-products of smelting operations and continued as a main activity at the site until the market collapsed in the late 1950s.

A century of handling hazardous materials and chemicals has resulted in significant environmental degradation of the Deloro Mine Site. Large quantities of refining slag, mine tailings, calcium arsenate, and arsenical pesticides remained at the site. Fuels, chemicals, and raw materials, such as sulphuric acid, coke, lime, soda ash, caustic soda, liquid chlorine, salt, scrap iron, sodium chlorate, and fuel oil were handled at the site. Radioactive slag and tailings were produced as a result of the re-refining of by-products from uranium refining.

The Ontario government stepped in to take control of the site in 1979 due to failure of the owner to control environmental releases. The MOE has been in care and control of the site since that time. Several rehabilitation actions have been implemented at the site to date that have significantly reduced releases from the site. In 1979, the annual average loading of

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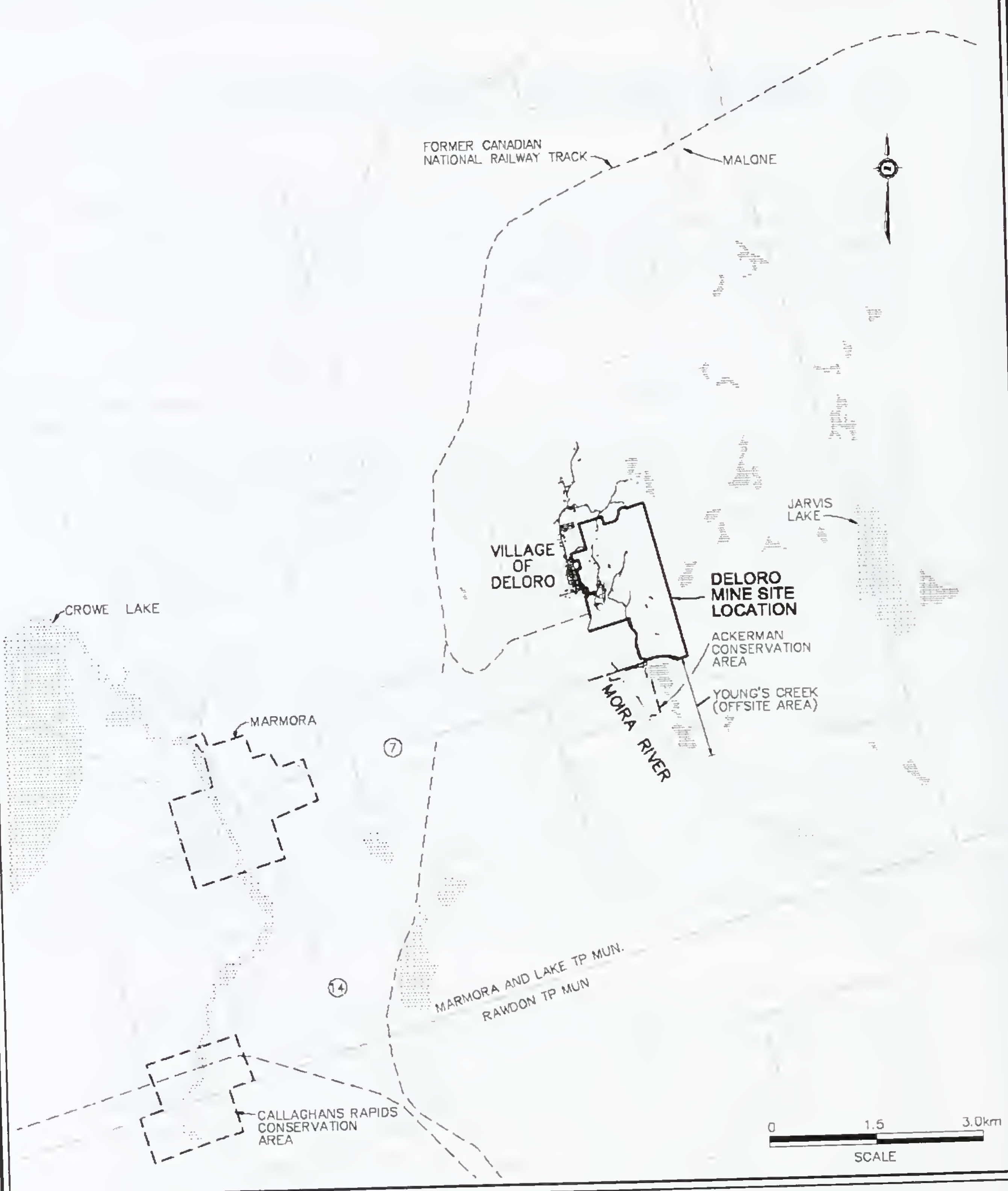
FORMER CANADIAN NATIONAL RAILWAY TRACK
MALONE
JARVIS LAKE
VILLAGE OF DELORO
DELORO MINE SITE LOCATION
ACKERMAN CONSERVATION AREA
YOUNG'S CREEK (OFFSITE AREA)
MOIRA RIVER
CROWE LAKE
MARMORA
7
14
MARMORA AND LAKE TP MUN.
RAWDON TP MUN
CALLAGHANS RAPIDS CONSERVATION AREA
0
1.5
3.0km
SCALE

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FIGURE 2-1
DELORO MINE SITE LOCATION

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arsenic to the Moira River was 52.1 kg/day. Since the arsenic treatment plant was put into operation in 1983, the arsenic loading to the river has been reduced by more than 80 percent, to an annual average of less than 10 kg/day. However, further work is required to reduce releases to acceptable levels and to secure the site for the long term. CH2M HILL was retained in April 1997 to provide consulting engineering and project management services for the Deloro Mine Site Cleanup.

2.2 Mine Area

Mining activities at Deloro were originally centred on the Gatling and Tuttle Shaft Area (i.e. Main Mine Area) of the site. This section was the location of a prominent quartz veining system along a regional structural feature. By today's standards the mine shafts in this area were all fairly limited in size, with small volumes of waste rock produced. Waste rock was dumped in the general vicinity of the mine shafts and is readily identifiable. Ore processing occurred in the Gatling and Tuttle Shaft Area; however, none is thought to have been carried out at the Hawkeye, 5 Acres, Pearce, and Cook's Shaft areas. Limited quantities of waste rock are also associated with the former Hawkeye, 5 Acres, Pearce, and Cook's Shaft areas. All other onsite mine workings appear to have been exploratory trenches and adits with minimal waste rock production.

Based on historical research carried out by Commonwealth Historic Research Management Limited (1988), the ore processing was contained to the area to the west of the Red Shaft, located in the areas designated in this report as the Historic Laboratory Area and the Historic Cyanide Mill Area, and in the central Industrial Area to the south. No other parts of the Mine Area are known to have been used for the processing of ores, or for metallurgical research.

2.3 Problem Definition

For the purposes of problem definition and remedial alternative assessment, the Mine Area of the Deloro site is dealt with as two main parts: the Main Mine Area and the Remote Mine Area. This two-fold division of the Mine Area is necessary since the environmental problems and conditions in each part are distinctly different, as are the remedial alternatives. Table 2.1 summarizes the division of the two parts of the Mine Area, and lists the primary issue of environmental concern (i.e. problem) associated with each. Additional description of each issue/problem is contained in the subsequent paragraphs of this report.

The identified wastes in the Main Mine Area are waste rock, incidental waste deposits, and heavily impacted soils that are present on the ground surface and the shallow subsurface. Water quality impacts to the Moira River in this area include groundwater discharge from the Tuttle Shaft and surface runoff from the contaminated waste rock, soils, and concentrated mine wastes. In the Remote Mine Area, waste rock contains high arsenic levels; however, the impacts to water quality associated with these remote waste rock areas are considered to be insignificant relative to those occurring at the Gatling and Tuttle Shaft Area. Shallow soils containing arsenic and other constituents above the MOE cleanup guideline for potable groundwater conditions can create an unacceptable impact and require management.

TABLE 2.1
AREA SPECIFIC PROBLEMS ASSOCIATED WITH THE MINE AREA

Component of Mine Area	Location of Issue/ Problem within area	Overall Issue/Problem
1. Main Mine Area	Gatling/Tuttle Shafts	Waste rock, heavily impacted soils and groundwater discharge (arsenic is greatest concern)
	Red Shaft	Heavily impacted soils (arsenic is greatest concern)
	Moira River	Contaminant impacted bottom sediment (arsenic is greatest concern), inputs of impacted groundwater, impacted surface water runoff from mine waste and heavily impacted soil, potential flushing during extreme storm events
2. Remote Mine Area	Former Mine Shafts – Hawkeye, 5 Acres, Pearce, Cook's	Waste rock
	Undeveloped Areas	Shallow impacted soils (arsenic is greatest concern)
	East Bank Seep at Moira River	Impacted groundwater discharge (arsenic is greatest concern)

While it is clear from the Onsite Data Summary report (CH2M HILL, February 2002) that there are low levels of contaminants throughout the Mine Area, this report will focus on areas of highest contamination and/or those of highest risk to human or animal health. While developing solutions that manage any unacceptable risks, it is acknowledged that wholesale removal of all mine site soils will result in the destruction of second growth forest if the intent is to remove all traces of contamination. Follow-up risk assessment once the recommended approach is in place will determine the extent of follow-on work that may be required, if any.

3. Existing Conditions

This section focuses on describing the existing site and environmental conditions within the Mine Area. It provides descriptions of the physical setting, the natural environment and the social conditions of the Deloro Mine Site and the Mine Area. This information forms the basis for identifying and evaluating viable remediation alternatives.

3.1 Operations

Current operations with respect to the Mine Area include:

- Monitoring Moira River water quality
- Monitoring groundwater quality
- Recording groundwater levels
- Pumping and treatment of contaminated groundwater from the Tuttle Shaft
- Monitoring rehabilitated mine workings
- Site security

3.2 Physical Setting

This section will outline the physical characteristics that will form a part of the final rehabilitation strategy for the Deloro Mine Site.

3.2.1 Climate

The Deloro area and the surrounding region receives an average yearly precipitation of 889 mm (Environment Canada, 1990). Maximum precipitation usually occurs in the month of September, with approximately 80 to 100 mm of rain. The spring growing season of April, May, and June accounts for about one quarter of the yearly precipitation. The months of September, October, and November account for about one quarter of all precipitation either as rain or snow.

The spring to fall average mean temperature is 16.9°C. The winter mean temperature is -7.4°C. The daily minimum average temperature for January and February is -13.4°C and the daily maximum highs average 25.3°C for the June to August period. The minimum and maximum average temperatures result in a maximum annual range of approximately 38.7°C. The record high was recorded in the summer of 1988, when temperatures exceeded 40.6°C over a seven-day period. The record low for the area is -40°C. Winds prevail from the west for the months from November to March and from the southwest in the spring and summer months.

3.2.2 Topography

In general, the ground surface at the Deloro site slopes to the south and to the east, toward the Moira River. Elevations over the site range from approximately 210 metres above sea level (masl), along the north boundary of the site, to approximately 185 masl, along the banks of the Moira River and in low-lying areas in the south of the property.

The surface topography and drainage have been extensively altered over the more than 100 years of mining, refining and manufacturing activities on the site.

Figure 3-1 shows the principal topographic features of the Deloro site.

3.2.3 Geologic Setting

The general geologic setting involves the mine site being located at the contact between Precambrian basement rocks and overlying Palaeozoic sedimentary rocks. Bedrock is exposed primarily at the north end of the site and along the Moira River, which passes through the MOE-controlled property. Young's Creek to the east of the site is established in a topographic depression flanked by low bedrock scarps and outcrops.

Bedrock Geology

Precambrian metasedimentary and metavolcanic rock forms the bedrock under most of the site except for the western edge of the property, which is underlain by Palaeozoic limestones and shale, and the eastern portion of the property, which is underlain by the Deloro Pluton—a felsic intrusive ranging from granitic to syenitic in composition (Chapman and Putnam, 1984). The syenitic phase of the intrusion is more prevalent on the southern half of the Deloro Pluton. A few skarn lenses occur within 300 m northwest and southwest of the major mine shafts. Granitic phases include syenite, granite, and diorite. The granite is typically pink, massive, medium-grained, and well jointed. The bedrock generally has a northwesterly strike and dips steeply. Joint orientations in the rock trend northeasterly and northwesterly. Frequent weathered fracture planes at 60 to 80 degrees from horizontal were noted in the granite below the cut-off wall along the Moira River.

The surface of the Precambrian bedrock is very irregular and reflects weathering processes during early Palaeozoic times prior to the deposition of the limestone strata that now covers much of the area west of the property. The irregular bedrock surface often protrudes through the overburden forming prominent bedrock knobs over much of the site.

Overburden Geology

The bedrock over much of the site is covered by natural overburden, clay fill, building rubble, tailings, slag, or a mixture of all of these. The natural overburden consists primarily of silty clay with minor amounts of silty sand and peat. These native soils are generally found in areas of low topography. The overburden is generally thin (less than 3 m) but is up to 9 m thick in some areas.

3.2.4 Hydrogeology

Groundwater flow at the Mine Area is altered to some extent by manmade features such as abandoned underground mine workings, exploratory blasting, and a groundwater collection system at the Tuttle Shaft.

Groundwater flows beneath the surface through a combination of both overburden and bedrock. In some instances, the flow may be through the bedrock only. In general, the groundwater flow direction in the Main Mine Area is easterly and southeasterly, toward the

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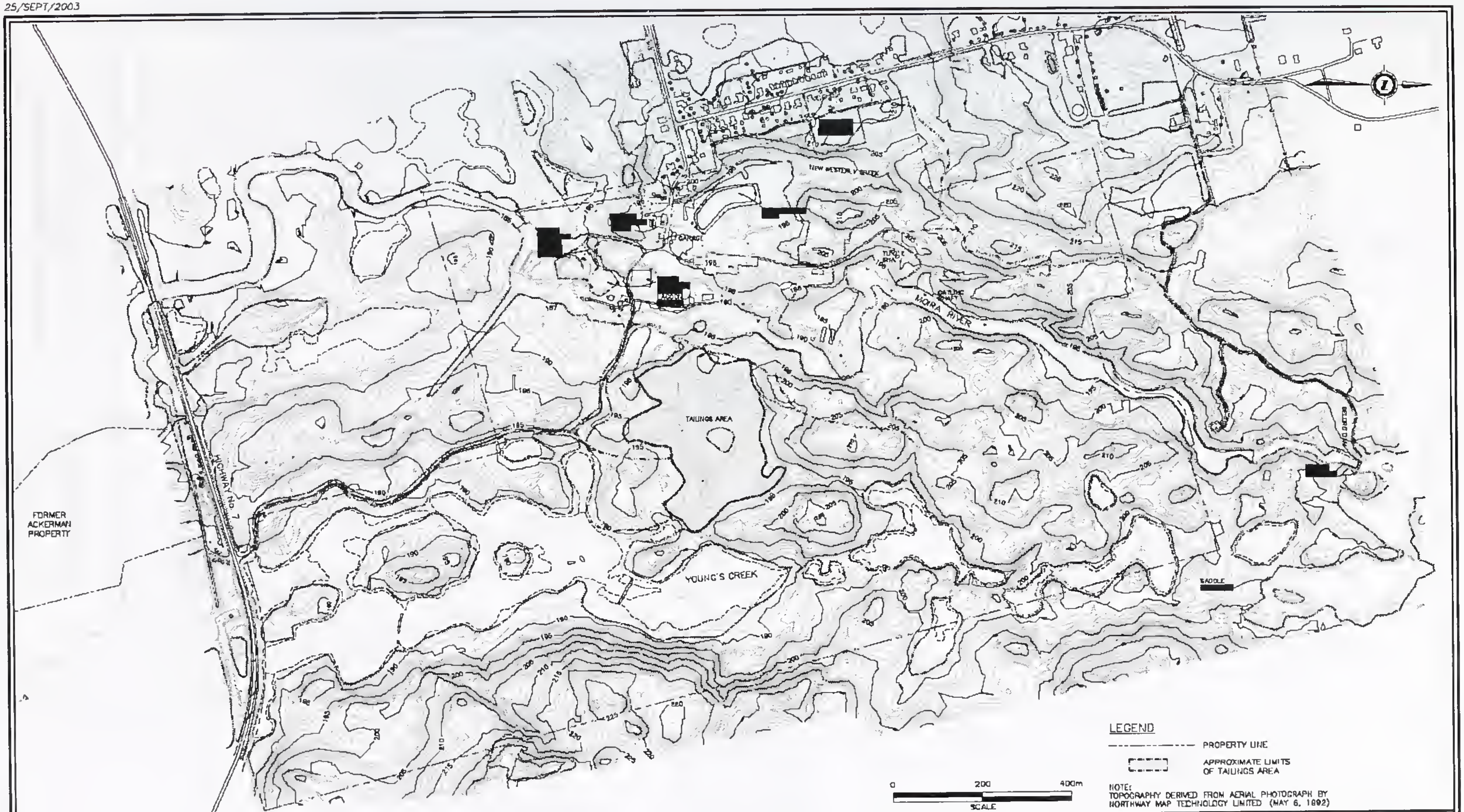

NOTE:
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPH BY NORTHWAY MAP TECHNOLOGY LIMITED (MAY 6, 1992)

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PROJECT No 119548

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-1
SITE TOPOGRAPHY

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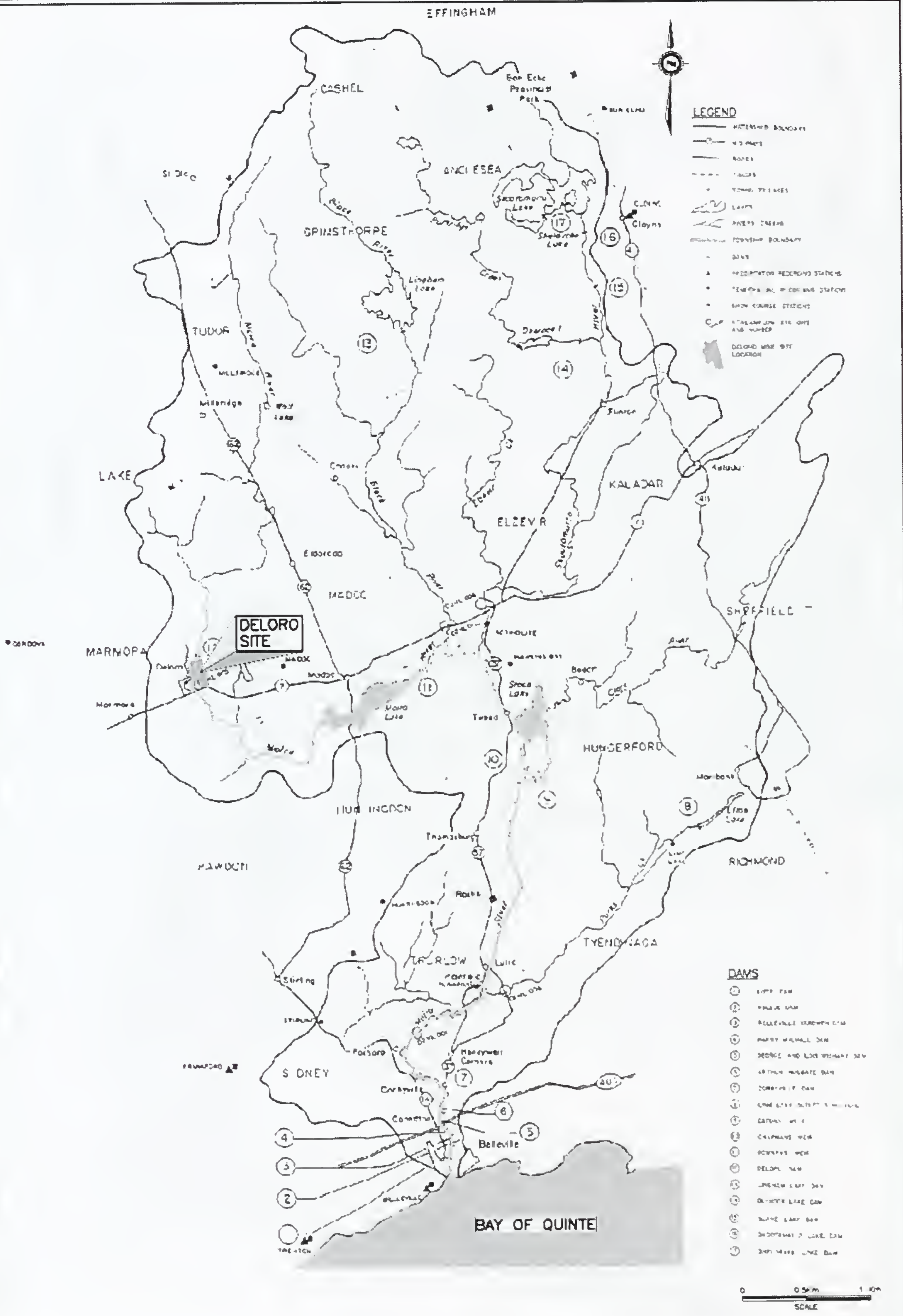

CH2MHILL

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-2
MOIRA RIVER WATERSHED AREA

PROJECT No. 119548

Moira River. There is not adequate data to determine the groundwater flow direction in the Remote Mine Area. The inferred groundwater flow direction is presumed to be towards the main surface water features, the Moira River and Young's Creek.

In the overburden, groundwater flows occur primarily through more permeable material usually lying directly on the bedrock surface. In the bedrock, groundwater flows occur primarily along fractures, bedding planes, and similar geological features. Fracture frequency and aperture generally decrease with depth; therefore, groundwater flow through the bedrock is expected to be greater in the shallow bedrock. Bedrock flow patterns are influenced by zones of higher hydraulic conductivity associated with natural faulting and/or folding. The bedrock geology is complex, consisting of intrusive igneous rocks and associated bedrock structures including dykes, sills, xenoliths, and zones of intense mineralization (CH2M HILL, August 2001). These natural structures in the rock have led to a complex and heterogeneous system of bedrock fracturing and groundwater flow. Natural fracturing of the rock may also have been influenced in localized zones through blasting and mine development.

The vertical groundwater flow was determined to be upwards from water table measurements taken August 21, 1998 (CH2M HILL, August 2001), consistent with flowing artesian conditions that occur in the Tuttle Shaft.

A pumping station is located in the southeast corner of the Main Mine Area at the former Tuttle Shaft. The pump is operated in the summer months to intercept groundwater containing dissolved arsenic from reaching the Moira River during low-flow periods. During the operation of the pump, a conically shaped capture zone would form around the pumping station that would influence the groundwater regime and result in increased flow towards the Tuttle Shaft. The area of influence for this pumping station has not been determined.

3.2.5 Hydrology

The Moira River watershed, which includes the Deloro site, is comprised of an area of approximately 2,750 km^2 and flows from this watershed are discharged into the Bay of Quinte on the northern shore of Lake Ontario. Figure 3-2 shows the Moira River watershed area. The Moira River originates in an area of Precambrian rock about 100 km north of the Bay of Quinte. Precambrian rock is exposed at much of the surface in the northern part of the basin but is underlain by as much as 83 m of Palaeozoic sedimentary rocks consisting mainly of limestone, dolostone, shale, and sandstone in the southern part of the basin. Sand and gravel of glaciofluvial origin, as well as organic deposits, are the primary overburden materials in the northern half of the watershed, while glacial till, glaciofluvial sand and gravel, and glaciolacustrine sand, silt, and clay predominate in the southern portion of the watershed.

The Moira River flows through Wolf, Moira, and Stoco Lakes. The site is located approximately 20 km upstream of Moira Lake and is bisected by the Moira River. The majority of the buildings and former processing areas of the mine are located on the west side of the river (i.e. the Industrial Area) while the primary tailings disposal area is to the east of the Moira River and west of Young's Creek, (i.e. the Tailings Area).

Bend Bay, a 21-ha widening of the Moira River, is located approximately 16 km downstream of Deloro and 3 km upstream of Moira Lake. Bend Bay is reported to have a mean water depth of 1 m and a residence time of 0.6 days. Moira Lake is essentially a shallow enlargement of the Moira River and is characterized by two distinct basins. The west basin has a surface area of approximately 200 ha, a mean depth of 4 m, and a maximum depth of 6 m. The east basin has a surface area of 600 ha, a mean depth of 4 m, and a maximum depth of 11 m. The residence time of water in Moira Lake is reported to range from 0.34 years to as long as 4.38 years in the summer (Kilborn, 1983). The west and east basins of Moira Lake are considered to be well mixed during the spring and fall, but transient thermoclines develop during the summer at deeper locations within the two basins limiting vertical mixing. The Moira River represents the primary flow into and out of Moira Lake.

Floodplain Mapping

Floodplain mapping was performed for relevant areas (e.g. potentially impacted areas) in both the Moira River and the onsite portion of the Young's Creek watershed sub-catchments (CG&S, November 1998). Floodplain mapping was not completed for the offsite portion of Young's Creek as part of the above noted study. In general it could be expected that similar flood effects would also occur in the offsite portion of the creek with some variations resulting from the steeper gradients in the Young's Creek channel, the influence of the beaver dams, and the influence of the bridge culvert under Highway 7. The floodplain elevations were generated using the hydrologic model BOSS HEC-2™, a water-surface profile computation program. This program is widely used in the field of floodplain management.

In accordance with the Ontario Ministry of Natural Resources guidance documents, the Zone 2 regulatory flood level for the 100-year flood was modelled. Due to the lack of storm flow data for Young's Creek Area, floodplain mapping for this subcatchment was based on the assumption that the 100-year flow would not exceed 30 percent of the 100-year storm flow for Moira River. Floodplain mapping was performed for the following flows:

• 10 percent of the 100-year flow through Moira River	5.49 m^3/s
• 20 percent of the 100-year flow through Moira River	10.98 m^3/s
• 30 percent of the 100-year flow through Moira River	16.47 m^3/s

It should be noted that several inherent limitations of the model exist, due to the lack of flow data as well as the relatively flat nature of the Young's Creek Area, particularly in the onsite portion of the creek. These limitations are explained in more detail in the Floodplain Mapping Final Report (CG&S, November 1998a). Flow velocities for the 100-year storm flow are shown in Table 3.1.

The flood risk maps in Figures 3-3 and 3-4 show the 100-year flood boundary and the location of the cross-sections used in the floodplain model. The model predicts that in the event of a 100-year storm, the Tailings Area would remain above the flood waters of both the Moira River and Young's Creek.

TABLE 3.1
FLOW VELOCITIES IN YOUNG'S CREEK WITH A FLOW EQUAL TO 30 PERCENT OF THE 100-YEAR STORM FLOW THROUGH MOIRA RIVER

Cross-Section Number (m)	Channel Mean Flow Velocity (m/s)	Cross-Section Number (m)	Channel Mean Flow Velocity (m/s)
0	0.78	1505	1.7
42	0.52	1520	0.59
55	1.83	1590	2.23
83	1.62	1795	0.42
99	0.3	1920	0.97
135	0.23	1995	2
215	0.16	2055	0.84
565	0.27	2215	0.47
950	0.2	2435	0.19
1265	0.35	2600	1.33
1445	0.96	2620	0.53

The active and inactive ferric arsenate sludge lagoons in the Industrial Area would also remain above the floodwaters. However, the third inactive wastewater lagoon (south of the two ferric arsenate lagoons) is predicted to be under flooding waters. The floodplain for the Moira River tends to be narrow, except for the area immediately downstream of the mine site bridge (CG&S, November 1998a).

3.3 Natural Environment

An ecological inventory of the Deloro Mine Site property was conducted by CH2M HILL (CG&S, February 1999) during the summer of 1997. The objective of the inventory was to characterize fish, vegetation and wildlife habitat on the site, to assess the habitat characteristics that contribute to the various assemblages found, and to detect the presence of significant species or groups of species, which could constrain remediation options. The presence or absence of certain organisms was also used to provide preliminary information on whether there are qualitative effects of specific constituents at the site on fish, vegetation and wildlife. Readers are directed to the Ecological Inventory report for specific results (CG&S, February 1999).

3.3.1 Aquatic Ecology

All watercourses within the vicinity of the Deloro Mine Site sampled for fisheries (which were all within the area of potential contamination associated with past historical mining activities) can be classified as fish habitat. These watercourses support a fishery that is economically important as bait and forage fish for higher trophic levels and as game fish. Nineteen species of fish were captured during the ecological inventory. The species captured were typical of species in the geographic area in warmer reaches of clear flowing streams and marshes. Ages ranged from young of the year to large adult fish, suggesting that spawning is occurring in these reaches. There were no threatened or endangered species of fish found. No evidence of water quality impairment can be derived from fisheries community sampling results, (CG&S, February 1999).

3.3.2 Terrestrial Ecology

No rare plant communities were found on the site. Nor were there any rare, threatened or endangered species of plant or animal life found. The composition of plant communities was typical in quality for this location, which is intermediate between southern and northern Ontario climatic zones and levels of soil disturbance. Wildlife species were also typical of extensive forests in this area. For further details, see the Ecological Inventory report (CG&S, February 1999).

Plant and animal communities, whether they contained waste or not, were typical of the habitat in which they were found. The type of vegetation present primarily determined wildlife communities. It was not possible to draw conclusions about the affect of constituents on plant communities in upland areas or on wildlife (GC&S, February 1999).

Succession in remediated areas will likely proceed slowly in areas where bedrock is close to the surface, as these areas are nutrient- and moisture-deficient. Succession will likely proceed from early successional communities, such as the one found on the tailings cap, through more advanced successional communities to communities that will ultimately be determined by soil conditions, microclimate and surrounding vegetation. It is recommended that native species currently found in soils over bedrock be used for restoration after remediation, as they are well adapted to these conditions.

3.4 Social Conditions

The Mine Area is located in the old Township of Marmora and Lake.[1] Young's Creek originates in an area of low topography just south and east of the Deloro Dam and Reservoir and flows in a southerly direction before discharging into the Moira River approximately two kilometres south of Highway 7. The Moira River continues easterly into Moira Lake and, from there, flows southerly to the Bay of Quinte.

The land use along the Moira River within the old Township of Marmora and Lake is primarily zoned as environmentally protected areas, with the surrounding land uses primarily zoned as rural. Development along the Moira River and Young's Creek, from Deloro to Moira Lake, is generally sparse. The Moira River Conservation Authority indicated that 11 houses and three farms are adjacent to this section of the Moira River. Nine of these houses are located at the mouth of the river at Moira Lake.

Use of the Moira River, Young's Creek and Moira Lake within the old Township is primarily recreational, consisting of fishing and boating. Potable water within the Township is obtained primarily via private wells. Discussions with the Moira Lake Property Owners' Association also indicated that most landowners in the area are aware of the concerns associated with water quality, and consequently there are no potable uses of river or lake water. There appears to be very little agricultural land near the Moira River, Young's Creek or Moira Lake. Consequently, use of the river or lake for agricultural purposes is also unlikely. Readers are directed to the *Survey of Moira River Water Use-Update, Final Technical Memorandum* (CG&S, October 1998c) for further details.

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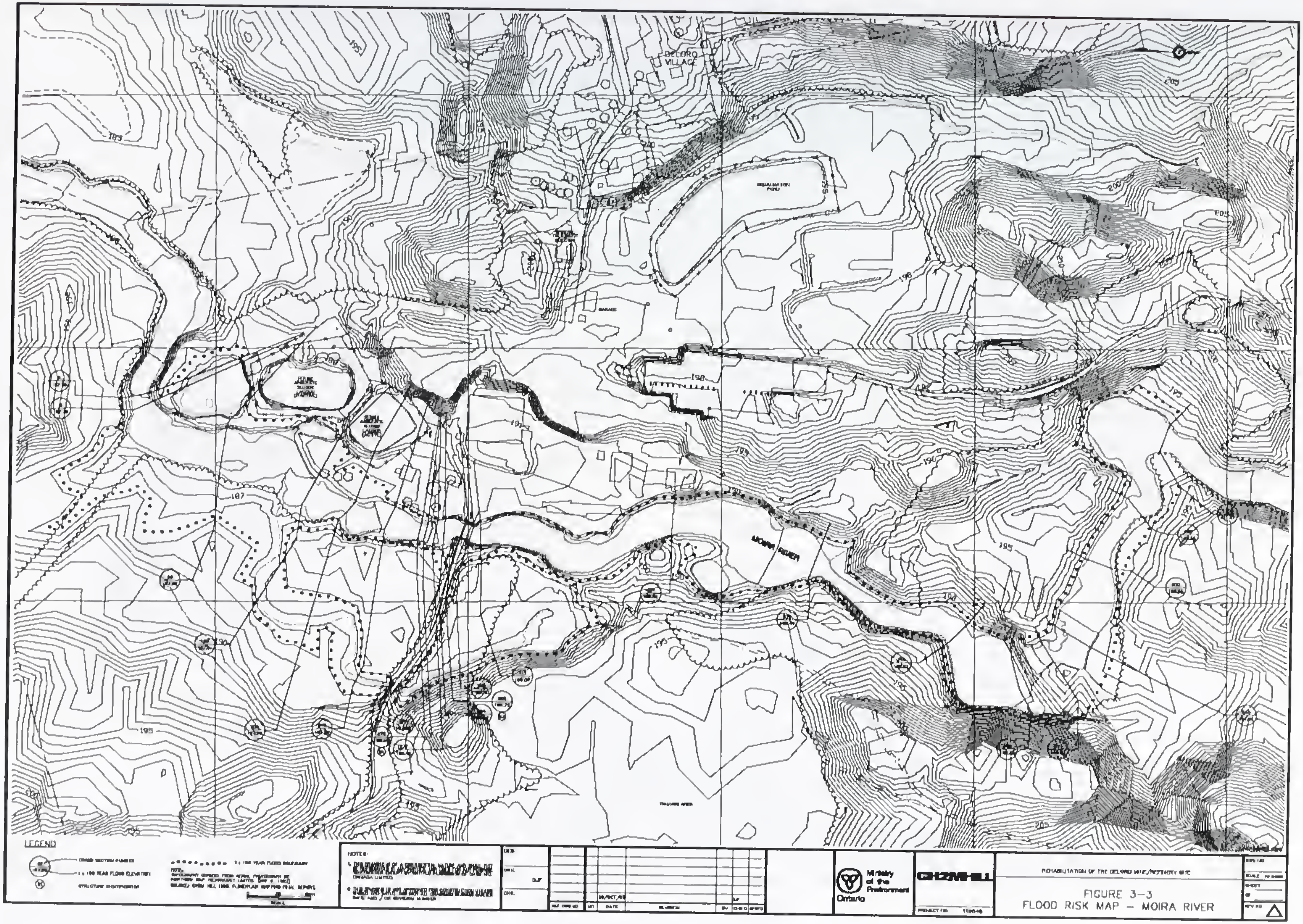
[1] The recent amalgamation has changed the jurisdiction this township falls under



REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-3
FLOOD RISK MAP – MOIRA RIVER

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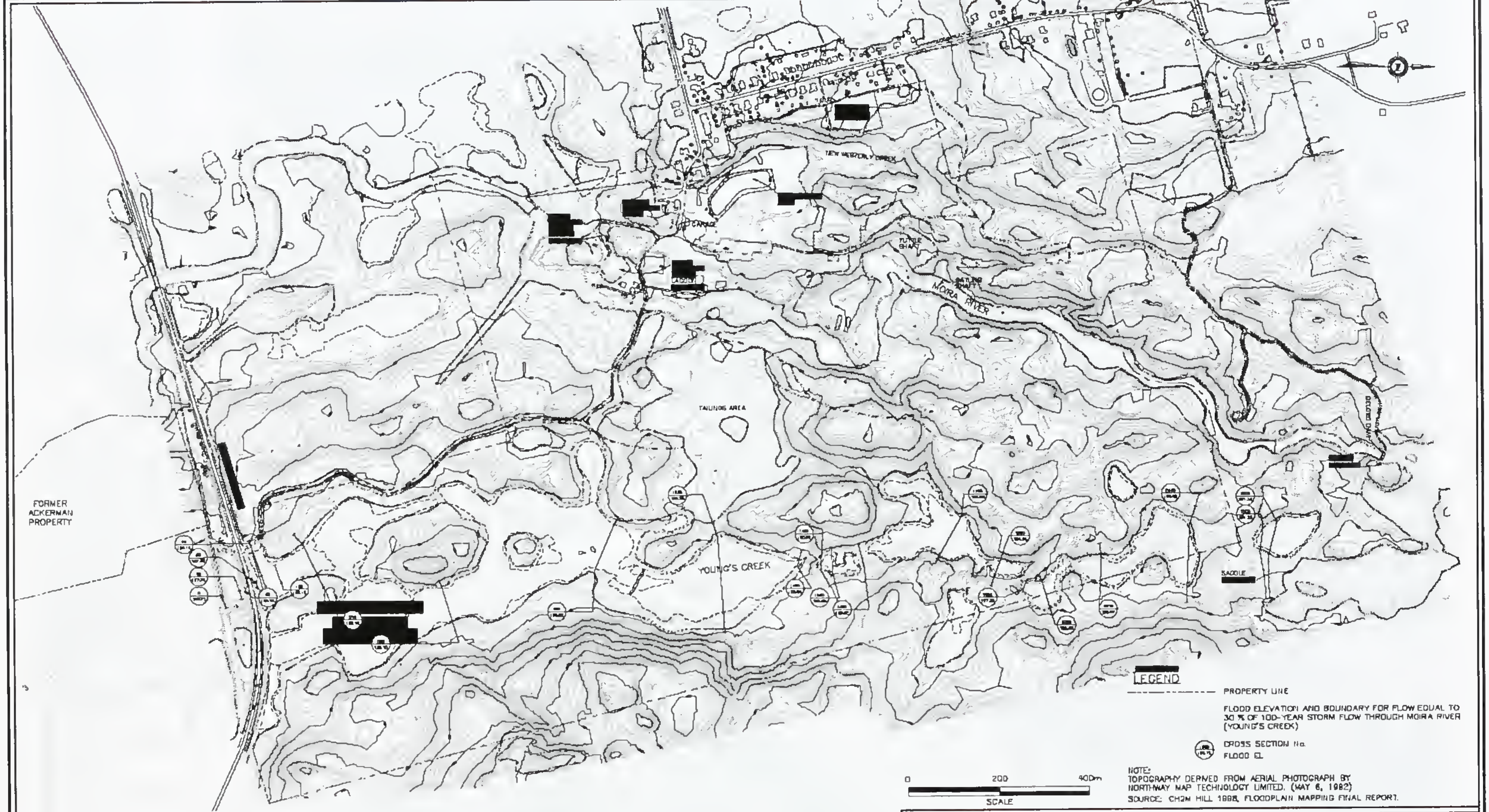

LEGEND

PROPERTY LINE

FLOOD ELEVATION AND BOUNDARY FOR FLOW EQUAL TO 30 % OF 100-YEAR STORM FLOW THROUGH MOIRA RIVER (YOUNG'S CREEK)

CROSS SECTION No.
FLOOD EL

NOTE:
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPH BY NORTHWAY MAP TECHNOLOGY LIMITED. (MAY 6, 1982)
SOURCE: CH2M HILL 1988, FLOODPLAIN MAPPING FINAL REPORT.

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-4
FLOOD RISK MAP
YOUNG'S CREEK

3.5 Physical Conditions in the Mine Area

The environmental conditions of the Main Mine and Remote Mine Areas are discussed below, together with a summary of the associated issues concerning heavily impacted soil, groundwater, river sediment, and waste material. For additional detail concerning these areas of the site, readers are directed to the reports completed by CH2M HILL, Steffen, Roberston & Kirsten (Canada) Inc. (SRK), and others that are listed in the References section of this document. Arsenic, cobalt and copper loadings to the Moira River from sources within the Main and Remote Mine Areas are summarized in Table 3.2.

3.5.1 Main Mine Area

The general boundaries of the Main Mine Area are depicted on Figure 1-1. This portion of the Deloro site includes the general area surrounding the former Gatling, Tuttle, and Red Shafts, located immediately north of the Industrial Area. Terrain here is highly disturbed, largely as a result of waste disposal and development associated with historical mining activity. Some locations within this area have been cleared of waste rock for use as borrow material in the Tailings Area of the site. Most waste rock is present near the Gatling Shaft. Areas between the Gatling, Tuttle, and Red Shafts are covered mainly by a silty sandy soil matrix which appears as native or re-worked material depending upon the location (CH2M HILL, July 2002). Much of the ground surface is clear of mature trees, and vegetation consists primarily of weeds, shrubs, and tall grass. Mapping of the wastes present in this area was completed by SRK in 1997 (CH2M HILL, July 2002).

3.5.2 Remote Mine Area

The Remote Mine Area represents a large part of the Deloro site outside of the Industrial, Tailings, Main Mine, and Young's Creek Areas, and totals approximately 114 ha in size, (i.e. Northwest, Northeast, South and East Remote Mine Areas). The general borders of this portion of the site are shown on Figure 1-1. The Remote Mine Area consists of peripheral mine shafts and associated zones of waste rock, at the former Pearce, Cook's, Hawkeye, and 5 Acres Shafts. Beyond these shafts, Young's Creek, and the Industrial, Tailings, and Main Mine Areas, the Remote Mine Area consists of undeveloped, and mainly forested terrain (Figure 1-1). The primary issues of concern in the Remote Mine Area include shallow impacted soil.

3.6 Contaminants in the Main Mine Area

3.6.1 Waste Rock

Waste rock in the Main Mine Area was found to be high in arsenic, but with a very low acid generation potential (CH2M HILL, July 2002). Arsenic loading to the Moira River from the waste rock in this area is estimated to be approximately 10 kg/yr (SRK, 1998). Direct contact with this waste rock represents a potential human health risk.

3.6.2 Heavily Impacted Soils

Surface water runoff and infiltrating groundwater is impacted by heavily impacted soils and concentrated wastes in the Main Mine Area. Previous studies of the Gatling and Tuttle Shaft Area found that the uncontrolled dumping of ore processing and metallurgical wastes in this area has caused the local soils to be heavily contaminated with a variety of inorganic compounds, such as arsenic, mercury, lead, and cyanide. Figures 3-5 to 3-7 are taken from the *Deloro Mine Rehabilitation Project, Onsite Data Summary* (CH2M HILL, February 2002) and show plan drawings of the Mine Areas that are representative of the various parameters that have exceeded their respective Guideline for Use at Contaminated Sites in Ontario – Table A criteria.

Soil samples collected in the Gatling and Tuttle Shaft Area during previous field investigations indicate that significant arsenic contamination is present in the following areas:

- Red Shaft Area (greenish arsenic contaminated soil identified)
- Arsenic Dump, north of the Gatling Shaft (area thought to be an open dump site of arsenic powder)

Most surface water runoff in these areas drains to the Moira River in the immediate vicinity of the Tuttle and Gatling Shafts.

3.6.3 Contaminated Sediment

A large pool in the Moira River, located immediately to the east of the Tuttle Shaft, was identified as a potential sediment trap which could be acting as an arsenic source for this section of the river (SRK, 1998).

To assess the concentration of metals in the substrate of the pool as well as upstream and downstream of the Tuttle Shaft, CH2M HILL collected bottom sediment samples in August 1998. All results of the sediment sampling program are discussed in a report entitled *Technical Memorandum – Moira River Sediment Survey* (CH2M HILL, March 2001).

The findings of the above work are preliminary. A much more extensive study of sediments downstream of Deloro was completed in the Moira River Study (Golder, 2001). This study concluded that, although present, the contaminated sediments did not appear to indicate an adverse impact. The significance of contaminated sediment in the Moira River at the Deloro site will be re-examined as part of an ecological risk assessment.

3.6.4 Contaminated Groundwater Discharge From Mine Workings

Shallow Groundwater in Gatling and Tuttle Shaft Area

In August 1998, CH2M HILL installed two deep and two shallow monitoring wells in the vicinity of the Tuttle Shaft to assess groundwater flow to the Moira River and to assist in the evaluation of potential loading from deeper groundwater flowing through abandoned mine workings. These wells were also installed at sampling locations that may be used to monitor the effectiveness of a future remedial option. Key findings of this well installation and sampling program are discussed in the CH2M HILL report entitled *Monitoring Wells*

Adjacent to Tuttle Shaft (CH2M HILL, August 2001). The significant finding of this work identified:

- Of four groundwater samples collected from three of the monitoring wells, all contained arsenic at concentrations greater than the corresponding 1997 MOE Contaminated Sites Guideline Potable Water Criterion of 0.025 mg/L. Arsenic concentrations in the samples ranged from 11 mg/L to 63 mg/L.

Deep Mine Workings/Tuttle Shaft

A principal component of deep groundwater discharge to the Moira River is gravity flow from artesian discharge originating from the Tuttle Shaft. This discharge occurs during periods of time for which the shaft pumping system is shut down (e.g. winter months). This groundwater, and other deep groundwater that discharges directly to the river via open bedrock fractures, is a significant arsenic loading source. Elevated arsenic concentrations apparently result from groundwater contact with gold-bearing mineralized zones found in the abandoned mine workings. Table 3.2 lists the estimated loading from both the Tuttle Shaft discharge and the overall contribution from the Main Mine Area. Additional information concerning these loading estimates is contained in the *Development of a Sitewide Water and Load Balance, Final Report* (CH2M HILL, March 2002).

TABLE 3.2
ESTIMATED ARSENIC, COPPER, AND COBALT LOADINGS TO THE MOIRA RIVER

Component of Mine Area	Location and Issue	Arsenic (kg/yr)	Cobalt (kg/yr)	Copper (kg/yr)
Main Mine Area	Groundwater (excluding Tuttle Shaft)	189.9	0.0	0.1
Remote Mine Area	East Bank Seep Discharge	11.68	7.37	0.003
Main Mine Area	Tuttle Shaft (gravity discharge)	538.4	0.8	0.2
Main Mine Area	Gatling and Tuttle Shaft Area [1]	728.3	0.8	0.3

Notes:

Information is based on *Development of a Sitewide Water and Load Balance, Final Report*, CH2M HILL, March 2002.

[1] Tuttle Shaft gravity discharge loading is included in the total Gatling and Tuttle Shaft Area loading value

3.7 Contaminants in the Remote Mine Area

3.7.1 Undeveloped Area

The Remote Mine Area (Undeveloped Area) was not subject to mineral processing activity, although some historical mine exploration occurred at some locations. As a result, most of the land included in this area is forested with limited road access. An Ecological Inventory conducted by CH2M HILL in 1997 describes the overall environmental conditions found in this portion of the site, including physiography, biophysical habitats, and vegetation (CG&S, February 1999).

The MOE completed a phytotoxicological investigation in the vicinity of the former metals smelter at the Deloro site based on data collected in 1986-1987 (MOE, 1998). This study, which extended into portions of the Undeveloped Area, included the collection of over 100 soil samples that were analyzed for inorganic parameters including arsenic, cobalt, copper, zinc, and nickel. Some key information from this study that is relevant to the Undeveloped Area includes the following:

- On average, background shallow soil arsenic concentrations in the Deloro area were about six times the Ontario Typical Range (OTR) value of 11 ppm. Shallow soil arsenic concentrations in samples obtained in the Undeveloped Area ranged from approximately 7 to 500 ppm.
- Soil sampling included some of the forested zones of the site that were not subjected to direct mining activity.
- Other parameters, including cobalt, zinc, and lead were found in samples collected from the Undeveloped Area at concentrations exceeding the corresponding OTR values.
- The MOE noted that the source of this contamination was the former smelter/tailings complex based on soil contamination contouring. It was suggested that as a result of more than 100 years of mining, smelting, and manufacturing activity in Deloro, arsenic and metals have been dispersed across a large area, both through atmospheric emissions and through extensive ground-level fugitive emissions from heavily impacted surface soil.

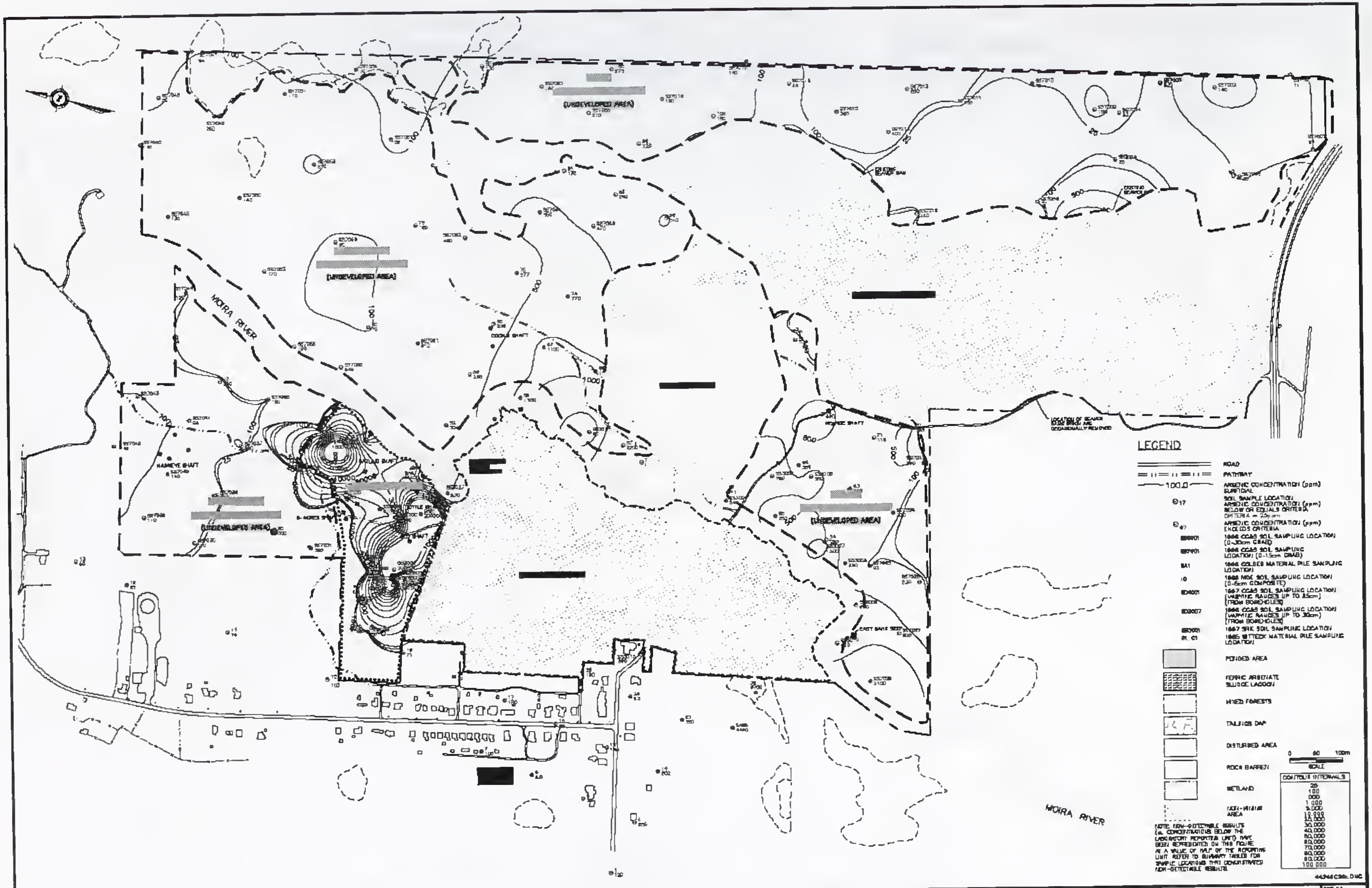
To obtain information required for the onsite risk assessment and to further delineate the extent of heavily impacted soil at the Deloro site, CH2M HILL conducted an assessment of arsenic and other contaminant concentrations in surficial soils in the Remote Mine Area (Undeveloped Area). Based on initial analysis of the soil arsenic data collected by CH2M HILL in August of 1998, presented in Tables SS-NW-2, SS-NW-4, SS-NE-2, SS-NE-4, SS-E-2, SS-S-2, and SS-S-4 as reported in *Deloro Mine Rehabilitation Project, Onsite Data Summary – Final Report* (CH2M HILL, February 2002), the following preliminary findings are noted:

- Of 68 samples collected from the Remote Mine Area (Undeveloped Area) soil arsenic concentrations ranged from approximately 6 to 2,100 ppm. The samples had a mean arsenic concentration of 224 ppm, and were collected within a depth range of 0 to 15 cm below ground surface.
- 98.5 percent of the samples exceeded the MOE Contaminated Sites Guideline, Table A residential/parkland land use criteria, using an arsenic value of 20 ppm. Over 60 percent of the samples contained arsenic at concentrations greater than 100 ppm.
- The wide distribution of elevated arsenic levels in shallow soils in the Remote Mine Area (Undeveloped Area) confirms the MOE's phytotoxicological investigation finding that atmospheric emissions from the former smelter complex have resulted in widespread soil contamination.

3.7.2 Waste Rock

Analysis of waste rock present at the Hawkeye, 5 Acres, Pearce and Cook's Shaft areas has indicated high waste rock arsenic concentrations (CH2M HILL, July 2002). This arsenic is naturally occurring and is associated with arsenopyrite mineralization. The waste rock has very low acid generation potential.

The waste rock arsenic concentrations represent a potential human health risk (SRK, 1998). The waste rock is not covered by topsoil and little or no vegetation cover is established. Until significant revegetation occurs, there is the potential for direct human exposure to arsenic via contact with the waste rock and/or through dust inhalation/ingestion.


LEGEND
ROAD
PATHWAY
100.0 ARSENIC CONCENTRATION (ppm) SURFICIAL
17 SOIL SAMPLE LOCATION ARSENIC CONCENTRATION (ppm) BELOW OR EQUALS CRITERIA CRITERIA = 25ppm
67 ARSENIC CONCENTRATION (ppm) EXCEEDS CRITERIA
1998 CCAS SOIL SAMPLING LOCATION (0-30cm GRAB)
1998 CCAS SOIL SAMPLING LOCATION (0-15cm GRAB)
BA1 1998 GOLDER MATERIAL PILE SAMPLING LOCATION
10 1998 MOE SOIL SAMPLING LOCATION (0-5cm COMPOSITE)
1997 CCAS SOIL SAMPLING LOCATION (VARYING RANGES UP TO 25cm) (FROM BOREHOLES)
1998 CCAS SOIL SAMPLING LOCATION (VARYING RANGES UP TO 30cm) (FROM BOREHOLES)
1997 SRK SOIL SAMPLING LOCATION
PL C1 1995 WITTECK MATERIAL PILE SAMPLING LOCATION
PONDED AREA
FERRIC ARSENATE SLUDGE LAGOON
MIXED FORESTS
TAILINGS CAP
DISTURBED AREA
ROCK BARREN
WETLAND
NON-MINING AREA
NOTE: NON-DETECTABLE RESULTS (i.e. CONCENTRATIONS BELOW THE LABORATORY REPORTING UNIT) HAVE BEEN REPRESENTED ON THIS FIGURE AT A VALUE OF HALF OF THE REPORTING UNIT. REFER TO SUMMARY TABLES FOR SAMPLE LOCATIONS THAT DEMONSTRATED NON-DETECTABLE RESULTS.
0 50 100m
SCALE
CONTOUR INTERVALS
20
100
500
1 000
5 000
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
100 000
MOIRA RIVER
MOIRA RIVER
(UNDEVELOPED AREA)
(UNDEVELOPED AREA)
(UNDEVELOPED AREA)
(UNDEVELOPED AREA)
HAWKEYE SHAFT
COOKS SHAFT
PILLAR SHAFT
BOTTLE SHAFT
S-ACRES SHAFT
BOWKER SHAFT
EAST BANK SEDIMENT
EXISTING BEAVER DAM
EXISTING SEAVORS
LOCATION OF SEAVER DAM AREA OCCASIONALLY REMOVED
100
500
1000
44346C38c.DWG

NOTES:

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DRN. D.REYS
CHK

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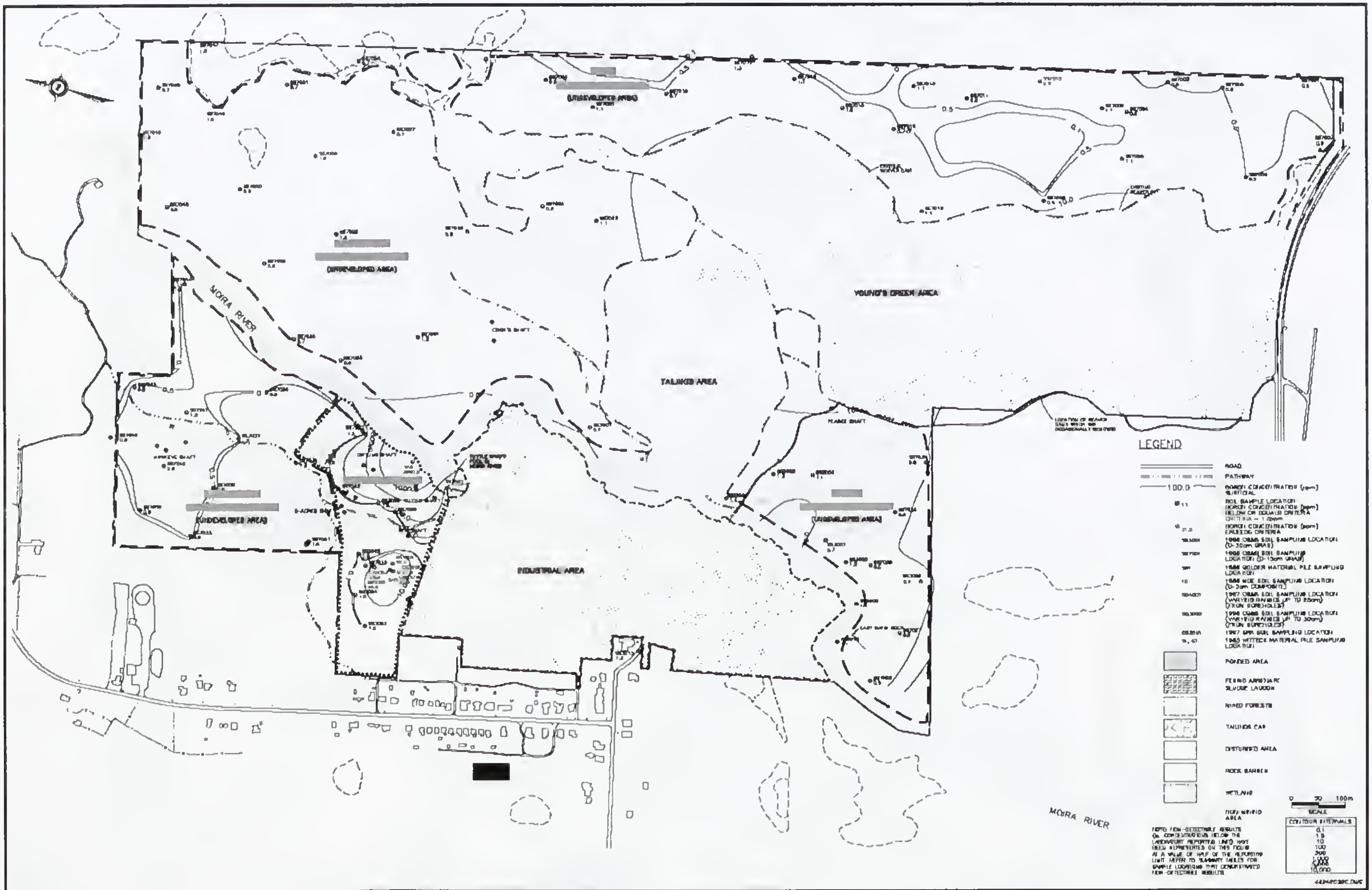
PROJECT NO

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-5
ARSENIC CONCENTRATION (PPM) CONTOURS SURFICIAL SOIL/WASTE MATERIAL MINE AREA

DWG N.S.
SCALE
SHEET
OF
REV NO △


YOUNG'S CREEK AREA
TAILINGS AREA
INDUSTRIAL AREA
(UNDEVELOPED AREA)
(UNDEVELOPED AREA)
(UNDEVELOPED AREA)
(UNDEVELOPED AREA)
MOIRA RIVER
MOIRA RIVER
COOK'S SHAFT
FLAKE SHAFT
0.5
0.5
100.0
LEGEND
ROAD
PATHWAY
BORON CONCENTRATION (ppm) ISOPLETHS
SOIL SAMPLE LOCATION BORON CONCENTRATION (ppm) BELOW OR EQUALS CRITERIA CRITERIA = 1.2ppm
BORON CONCENTRATION (ppm) EXCEEDS CRITERIA
1996 OMMS SOIL SAMPLING LOCATION (0-30cm GRAB)
1996 OMMS SOIL SAMPLING LOCATION (0-15cm GRAB)
1996 GOLDER MATERIAL PILE SAMPLING LOCATION
1996 MOE SOIL SAMPLING LOCATION (0-5cm COMPOSITE)
1997 OMMS SOIL SAMPLING LOCATION (VARYING RANGES UP TO 80cm) (FROM BOREHOLES)
1998 OMMS SOIL SAMPLING LOCATION (VARYING RANGES UP TO 30cm) (FROM BOREHOLES)
1997 SRK SOIL SAMPLING LOCATION
1983 WITTECK MATERIAL PILE SAMPLING LOCATION
PONDED AREA
FERRIC ARSENATE SLUDGE LAGOON
MIXED FORESTS
TAILINGS CAP
DISTURBED AREA
ROCK BARREN
WETLAND
NON-MINED AREA
NOTE: NON-DETECTABLE RESULTS (i.e. CONCENTRATIONS BELOW THE LABORATORY REPORTING LIMIT) HAVE BEEN REPRESENTED ON THIS FIGURE AT A VALUE OF HALF OF THE REPORTING LIMIT. REFER TO SUMMARY TABLES FOR SAMPLE LOCATIONS THAT DEMONSTRATED NON-DETECTABLE RESULTS.
0 50 100m
SCALE
CONTOUR INTERVALS
0.1
1.0
10
100
300
1,000
5,000
10,000
443491C39C.DWG

[redacted]

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		98/SEPT/09				

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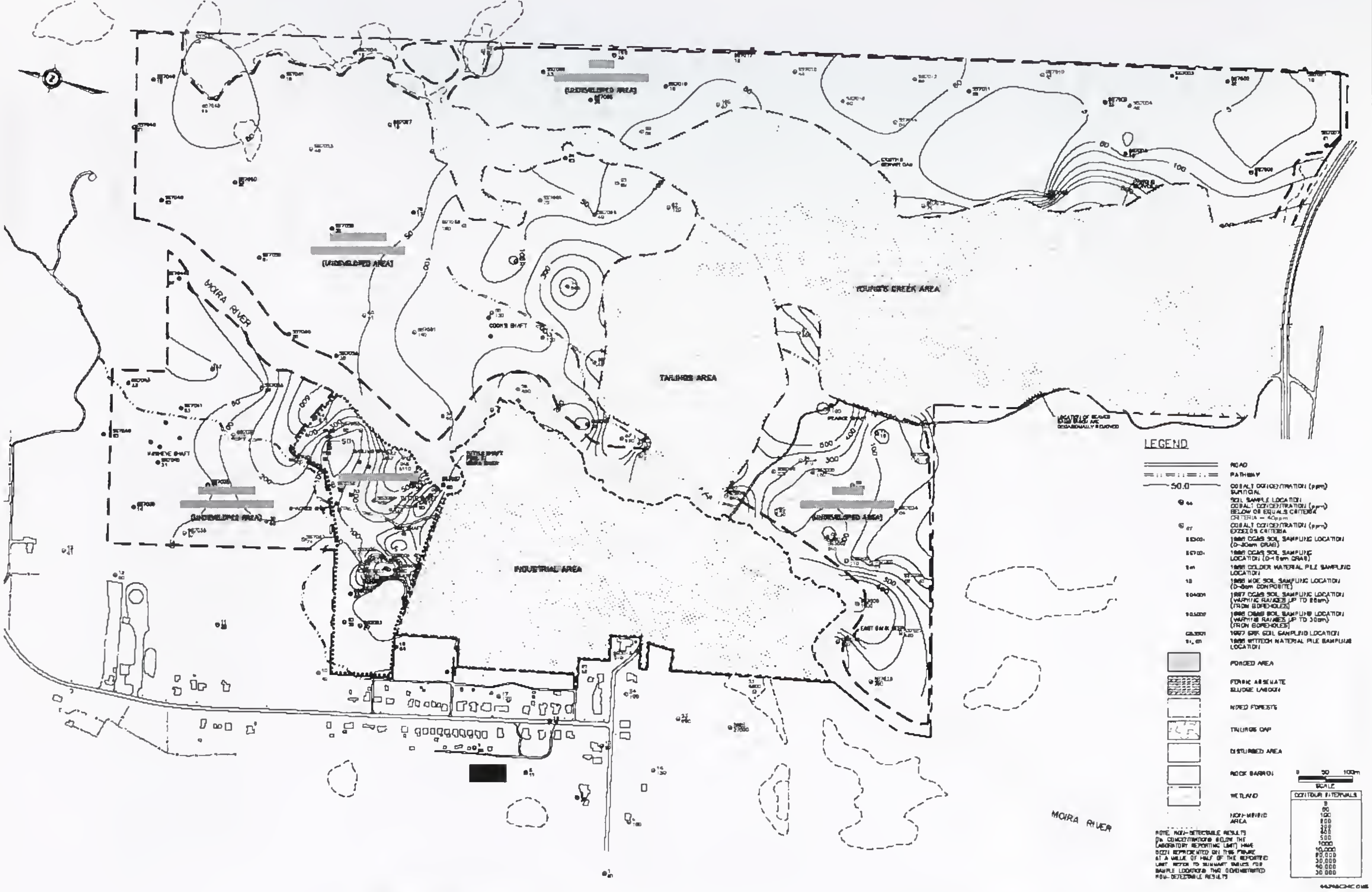
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3.6
BORON CONCENTRATION (PPM) CONTOURS
SURFICIAL SOIL/WASTE MATERIAL MINE AREA

DWG NO.
SCALE
SHEET
OF
REV NO. △



[redacted]
(UNDEVELOPED AREA)
[redacted]
(UNDEVELOPED AREA)
[redacted]
(UNDEVELOPED AREA)
[redacted]
(UNDEVELOPED AREA)
MOIRA RIVER
COOK'S SHAFT
TAILINGS AREA
YOUNG'S CREEK AREA
INDUSTRIAL AREA
PEARCE SHAFT
EAST SHAFT
[redacted]
MOIRA RIVER
LEGEND
ROAD
PATHWAY
50.0
COBALT CONCENTRATION (ppm) SURFICIAL
SOIL SAMPLE LOCATION COBALT CONCENTRATION (ppm) BELOW OR EQUALS CRITERIA CRITERIA = 40ppm
COBALT CONCENTRATION (ppm) EXCEEDS CRITERIA
1996 CCAS SOIL SAMPLING LOCATION (0-30cm GRAB)
1996 CCAS SOIL SAMPLING LOCATION (0-15cm GRAB)
1996 GOLDER MATERIAL PILE SAMPLING LOCATION
1996 MOE SOIL SAMPLING LOCATION (0-5cm COMPOSITE)
1997 CCAS SOIL SAMPLING LOCATION (VARYING RANGES UP TO 30cm) (FROM BOREHOLES)
1996 CCAS SOIL SAMPLING LOCATION (VARYING RANGES UP TO 30cm) (FROM BOREHOLES)
1997 GRK SOIL SAMPLING LOCATION
1996 WITTECH MATERIAL PILE SAMPLING LOCATION
FORCED AREA
FERRIC ARSENATE SLUDGE LAGOON
MIXED FORESTS
TAILINGS CAP
DISTURBED AREA
ROCK BARRON
WETLAND
NON-MINING AREA
0 50 100m
SCALE
CONTOUR INTERVALS
0
50
100
200
300
400
500
1000
10,000
20,000
30,000
40,000
50,000
NOTE: NON-DETECTABLE RESULTS (i.e. CONCENTRATIONS BELOW THE LABORATORY REPORTING LIMIT) HAVE BEEN REPRESENTED ON THIS FIGURE AT A VALUE OF HALF OF THE REPORTING LIMIT. REFER TO SUMMARY TABLES FOR SAMPLE LOCATIONS THAT DEMONSTRATED NON-DETECTABLE RESULTS

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DRN. D.FOYS
CHK.

REV ISSUE NO.	NO.	DATE	REVISION	BY	CHK'D	APP'D
		01/SEPT/00				

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-7
COBALT CONCENTRATION (PPM) CONTOURS SURFICIAL SOIL/WASTE MATERIAL MINE AREA

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SHEET
OF
REV NO.

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3.7.3 East Bank Seep

The East Bank Seep was located on the east floodplain of the Moira River, about 300 m to 400 m south of the Deloro Arsenic Treatment Plant in an area of former geological exploration and mine shaft development, and was therefore considered as part of the South Remote Mine Area (Figure 1-1). Flow from the seep through a former drill hole and pipe was seasonal in nature and had been observed to dry up during summer months; therefore, inorganic loading to the Moira River from this seep was likely intermittant. In December 1997, the seep discharge was measured at a rate of 3.9 L/min. The seepage displayed a reddish-brown to orange appearance. Additional information concerning this seep is outlined in the report entitled *Deloro Mine Rehabilitation Project, Assessment of East Bank Seep – Moira River* (CG&S, November 1998b).

Seep water quality was assessed based on the mean of two samples obtained in October, 1997 by the Sierra Legal Defence Fund (SLDF) and the Ontario Clean Water Agency (OCWA) (CG&S, November 1998b). Seep samples collected in 1997 were compared to Provincial Water Quality Objectives (PWQO) and were found to exceed the corresponding objectives for arsenic, cobalt and nickel. The Interim PWQO for arsenic is 0.005 mg/L and the recorded mean concentration at the East Bank Seep was 11.4 mg/L. The mean concentration of cobalt in the seepage water was 7.19 mg/L, compared to the PWQO value of 0.0009 mg/L, while nickel was observed at a mean concentration of 1.16 mg/L, versus the corresponding PWQO value of 0.025 mg/L. The loading determined from the East Bank Seep, based on an average discharge rate between 0 (i.e. no flow) and 3.9 L/min, and the single sampling event performed by OCWA, was a maximum of approximately 11.7, 7.4, and 1.2 kg/year for arsenic, cobalt, and nickel, respectively.

In October 1998, CH2M HILL surveyed the elevation of the seep relative to the Moira River and investigated the depth of the seep drill hole. Based on this work, the drill hole was suspected to be approximately 21 m deep. Earlier reports proposed that this seep be plugged with low permeability material, and sealed to prevent further groundwater discharge. This information is available for reference in the report for the seep (CG&S, November 1998b).

This undertaking was considered to be relatively minor and on March 15, 1999, the MOE authorized OCWA to proceed with plugging the seep drill hole, as recommended in the East Bank assessment report (CG&S, November 1998b). The seep was plugged in June 1999 and is no longer considered a source of contaminant loading to the Moira River. Consequently, assessment of other approaches to mitigating discharge from this seep is not warranted, and has not been included in this report.

3.8 Summary

The Mine Area has been divided into two areas. The area most impacted by mining operations is the Main Mine Area. Contaminants include those that are present on the ground surface (waste rock, incidental waste deposits, and heavily impacted soils) and in groundwater discharge from the Tuttle Shaft and surface runoff from the contaminated waste rock, soils, and concentrated mine wastes. These sources represent potential human health risks and also impact the water quality of the Moira River. In the Remote Mine Area, waste rock contains high arsenic levels, although impacts to water quality are considered to be insignificant. Shallow soils containing arsenic and other parameters above the MOE cleanup guideline for potable groundwater conditions may have an unacceptable impact and require some level of management. The impacts to water quality associated with these soils in the Remote Mine Area are considered to be insignificant relative to those occurring at the Gatling and Tuttle Shaft Area (SRK, 1998).

The selected remediation alternative will need to address the local variations in site conditions and properties and the impact on the local ecology (second growth forest) and the Moira River. Addressing these concerns will therefore form a part of evaluating the remedial alternatives.

4. Alternatives Evaluation Process

4.1 Strategic Direction for Site Cleanup

In the early 1990s, MOE staff from Southeast Region (now MOE Eastern Region) reviewed the Deloro Mine Site Project with the then MOE Management Committee to determine a strategic direction for final site cleanup. The Committee was composed of several MOE Assistant Deputy Ministers (ADMs), the Deputy Minister (DM) and the Minister, as well as an ADM and Director from the Ministry of Northern Development and Mines (MNDM).

Based on a detailed analysis of site conditions and on previous experience gained in similar situations, the Committee recommended that onsite waste management options be favoured as primary remediation techniques to rehabilitate the site. The main reason for adopting this approach was the realization that complete cleanup to natural background levels would be extremely costly and may not represent the most prudent expenditure of public funds. It was also recommended that the cleanup work proceed under an exemption to the provincial Environmental Assessment Act. These two recommendations were endorsed by the Ontario Minister of the Environment in October 1991 and funds were then allocated to retain professional services to develop and implement a cleanup plan under the authority of the MOE. The latter recommendations were identified as "fundamentals" in the *Deloro Rehabilitation Plan* produced by the Southeast Region office of the MOE (now the Eastern Region office of the MOE) in September 1992 and formed an integral part of the request for proposal that was issued by the MOE in 1996 to select a consulting engineering firm to develop and implement a remedial plan for the Deloro Mine Site.

4.2 Closure Objectives

As described in the report entitled *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a), and in the above section, the strategic direction for site cleanup involves onsite management of wastes through isolation and containment methods as primary remediation techniques. Consequently, a pragmatic approach has been adopted where mitigative measures are directed at risk reduction. This translates into the following project objective:

> *To successfully rehabilitate the Deloro Mine Site to mitigate any unacceptable impacts on human health or the environment in compliance with relevant environmental policies and regulations*

To satisfy this objective, specific site-wide and distinct area closure objectives were developed. The site-wide closure objectives are as follows:

1. Reducing the loading of arsenic and other contaminants to the Moira River
2. Compliance with appropriate regulations and policy
3. Satisfy the general intent of the Mining Act and related draft regulations
4. Reducing/controlling impact/risk to acceptable levels
5. Demolition of unneeded buildings to ground level

6. Prioritizing remedial action implementation according to risk reduction
7. Minimizing perpetual operation and maintenance
8. Restoration of the site to reflect its natural surroundings
9. Securing the site for the indefinite future
10. Managing the wastes over the smallest possible area

These sitewide closure objectives were further refined into area specific closure objectives for each of the areas of the site. The area specific closure objectives for the Mine Area are presented in Section 5.1.

4.3 Overview of the Process to Generate and Evaluate Alternatives

The process applied by CH2M HILL to generate potential remedial alternatives for all areas of the Deloro site is illustrated in Figures 4-1 to 4-3. Initially, conceptual remediation methods that could have addressed some or all of the issues identified for each respective area of the site were identified. For instance, a method may address groundwater issues but not impacted sediment. These methods were evaluated with a screening process to identify which methods had the greatest potential to address the issues at the site, either alone or in combination with other methods. Improbable methods that did not have significant potential to contribute to a viable solution were eliminated early in the process. This resulted in a list of primary remediation methods that were retained for further evaluation.

The primary remediation methods were combined with enhancing features based on the judgement and experience of the project team to create a number of comprehensive remediation alternatives that addressed all of the environmental issues at the site. These comprehensive remediation alternatives were subsequently evaluated in a two-step process. The screening level evaluation again served to eliminate comprehensive remediation alternatives (as opposed to conceptual remediation methods that have been previously screened) that were unlikely to meet all of the remediation needs for the area. This second level of screening led to a short list of comprehensive remediation alternatives that were the subject of a more detailed evaluation. The detailed evaluation led to the identification of a recommended remediation alternative, which would be developed further and subsequently implemented to address the environmental issues at the site.

4.4 Generation of Comprehensive Remediation Alternatives

Significant efforts were invested through the years to characterize environmental conditions (i.e. soil, surface water, groundwater, air, human health risk, and ecological conditions) for all areas of the site. Such characterization studies were necessary to identify contaminants of concern, quantify contaminant concentrations and volumes, determine the media into which the contaminants were found, and assess contaminant mobility. It is as a function of these characteristics that potential conceptual remediation methods were initially generated.

The alternatives generation process involved consideration of the strategic approach described in Section 4.1, identification of conceptual remedial methods that CH2M HILL has either used on similar projects in the past, or identified in the scientific literature for the contaminants and media of concern, as well as specific exclusionary criteria dealing with the following:

- Effectiveness of the conceptual methods in question to remediate the site
- Satisfaction (in principle) of government regulations and guidelines
- Pre-established design closure criteria

These criteria were designed to eliminate improbable conceptual remediation methods early in the process so that valuable time and resources were not expended in the completion of a more detailed evaluation.

The methods developed for consideration were not intended to be an exhaustive evaluation of all conceivable methods, but a focused assessment of readily identifiable and proven methods that had good potential for successful application at the site. Consideration of experimental or developmental methods was considered beyond the scope of this evaluation. Professional judgement and practical considerations factored into the range and diversity of methods considered. For instance, where a proven and effective method was readily identifiable and cost-effective, limited consideration was made of other methods.

The first exclusionary criterion, the effectiveness of the conceptual remediation method, was used to evaluate the expected effectiveness of the method in solving the problem identified for the area (i.e. Can the conceptual remediation method contribute to a significant attenuation of unacceptable impacts on human health or the environment by way of reducing a component of the contaminant load?). The second criterion, the satisfaction of government regulations and guidelines, served to evaluate the capacity of the conceptual remediation method to meet relevant government legislation and guidelines. The third criterion, design closure criteria, was used to assess whether the conceptual remediation method was likely to satisfy the area specific design criteria, a combination of the closure criteria and remediation targets outlined below.

These design criteria were developed from a risk based approach that is summarized in the report entitled *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a). The risk based approach was used to identify areas of the site that pose the greatest risk and consequently served to prioritize remedial action to obtain the greatest reduction of contaminant release from the site as well as overall exposure to contaminants. Using risk assessment, remediation targets were set as follows:

1. Surface water from Young's Creek and the Moira River should satisfy, on average, the Interim Provincial Water Quality Objectives (PWQO) for three key contaminants (i.e. arsenic, cobalt and copper) at the Highway 7 crossing located approximately 600 m downstream (i.e. south) of the site.
2. Post-closure onsite arsenic concentration in air and soil should be, on average, below a concentration that will ensure that the probability of incremental lifetime cancer risk for onsite workers and potential recreational users of the site is less than 1:100,000.

To achieve these targets, site-wide closure objectives were translated to area-specific closure objectives (as stated in Section 5.1) that were refined into closure criteria that specifically address the following:

- Physical aspects
  - Design service life
  - Design floods
  - Seismic considerations
  - Minimum factors of safety
  - Perpetual disruptive forces
- Chemical aspects
  - Human health
  - Aquatic life
  - Terrestrial habitat
- Radiological aspects

These closure criteria will become closure plan design parameters for the selected remediation alternative, as described in the *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a).

4.4.1 Screening of Conceptual Remediation Methods

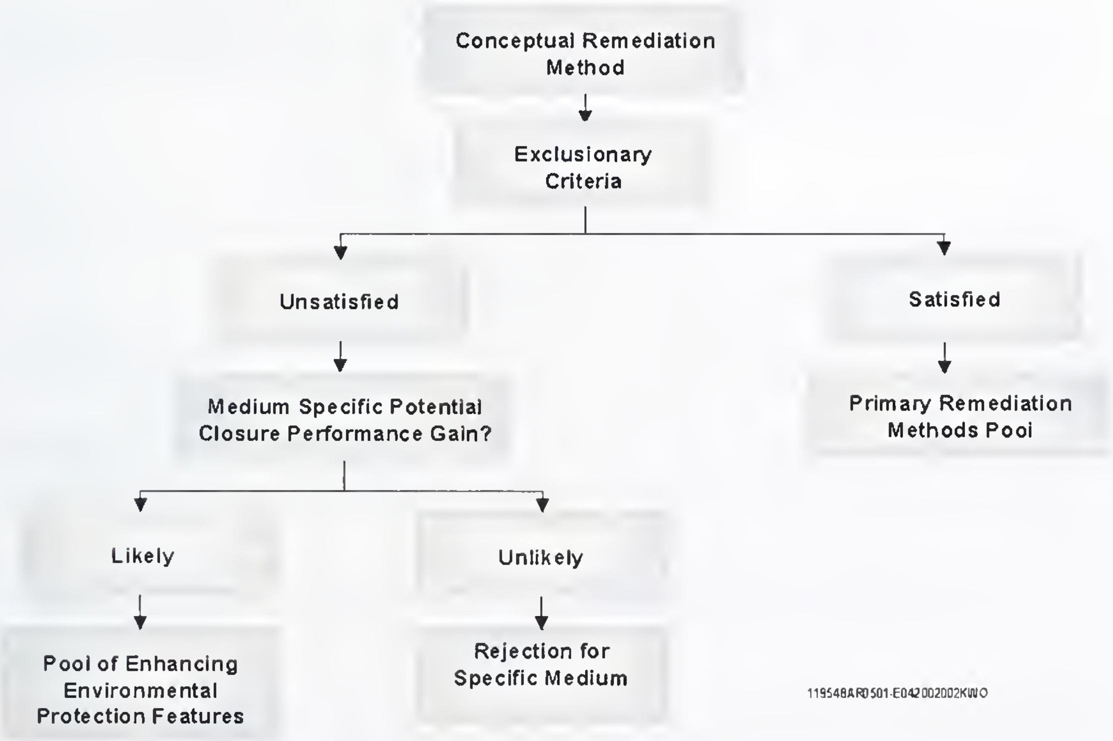
Each conceptual remediation method was consequently evaluated to determine whether it could (yes) or could not (no) meet the exclusionary criteria presented above. A "no" to any of these criteria eliminated the conceptual remediation method as a primary remediation method. A primary remediation method is defined as a method that had significant potential to address most of the environmental issues in this area of the site without further augmentation or enhancement. All criteria carried equal weight in the evaluation process; therefore, their order of appearance does not reflect their relative importance. Table 4.1 further synthesizes the intent of the exclusionary criteria used to generate remediation alternatives.

TABLE 4.1
EXCLUSIONARY CRITERIA – SCREENING OF CONCEPTUAL REMEDIATION METHODS

Exclusionary Criteria	Considerations	Measure
Effectiveness	Does the conceptual remediation method have the potential to solve one or more aspects of the problem? (i.e. Can it contribute to a significant attenuation of any unacceptable impacts on human health or the environment by way of reducing a component of the contaminant load?)	Yes – The conceptual remediation method has the potential to significantly reduce contaminant loads to the environment. No – The conceptual remediation method does not have the potential to significantly reduce contaminant loads to the environment.
Government Regulations and Guidelines	Does the conceptual remediation method conform in principle to applicable government regulations and guidelines relating to site rehabilitation? (e.g. Guideline for Use at Contaminated Sites, Mining Act and Rehabilitation Guidelines?)	Yes – The conceptual remediation method is more likely to conform. No – The conceptual remediation method is less likely to conform.
Design Closure Criteria	Is the conceptual remediation method likely to satisfy design closure criteria pertaining to site specific risk assessment of human health and environmental impacts if developed in greater detail?	Yes – The conceptual remediation method has the potential to satisfy design criteria. No - The conceptual remediation method has no potential to satisfy design criteria.

Rejection as a primary remediation method did not exclude further consideration of the method to augment another conceptual remediation method, particularly if the former showed significant potential to control the release or minimize the mobility of contaminants in a specific medium (groundwater, surface water, soil or air). Some methods were retained based on their potential for combination with other methods to create a comprehensive solution to the environmental issues in an area. Such combinations were termed "Comprehensive Remediation Alternatives". Other methods were retained as potential enhancements, which formed redundancies in the design, such as multiple barriers to contaminant release/migration. Figure 4-1 illustrates the process used to screen conceptual remediation methods.

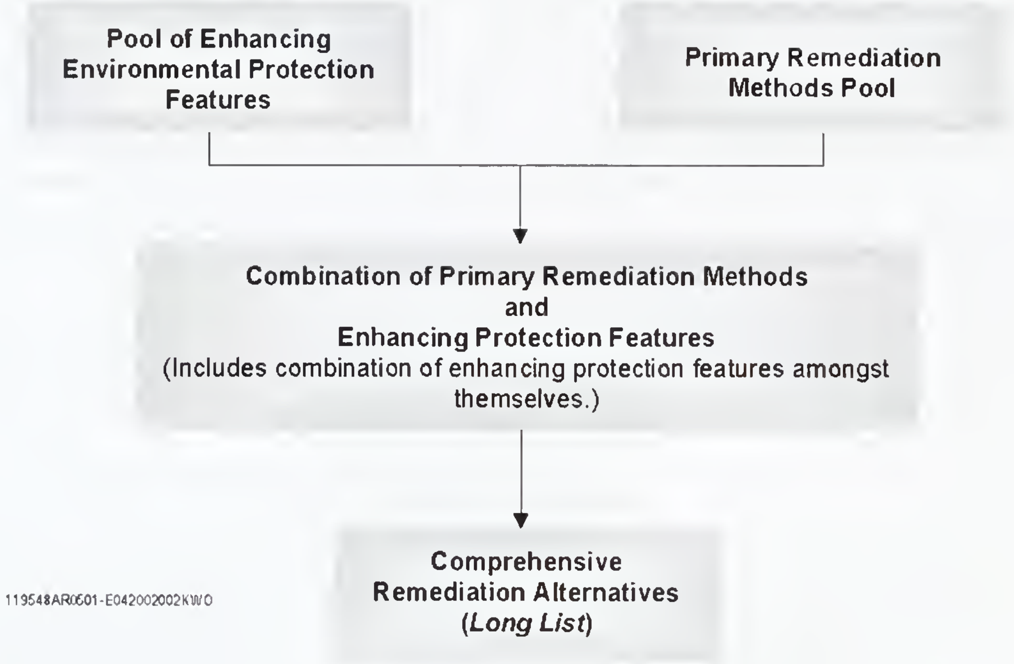
FIGURE 4-1
SCREENING OF CONCEPTUAL REMEDIATION METHODS – SCHEMATIC DIAGRAM


Conceptual Remediation Method
Exclusionary Criteria
Unsatisfied
Satisfied
Medium Specific Potential Closure Performance Gain?
Primary Remediation Methods Pool
Likely
Unlikely
Pool of Enhancing Environmental Protection Features
Rejection for Specific Medium
119548AR0501-E042002002KWO

4.4.2 Development of Comprehensive Remediation Alternatives

Figure 4-2 schematically illustrates the process used to generate comprehensive remediation alternatives for further consideration. Alternatives were developed from the list of primary remediation methods that have passed the screening level evaluation. Comprehensive remediation alternatives were developed to create potential solutions that addressed all of the environmental issues or problems in each area. Where primary remediation methods have been identified through the screening process, the team considered how the method could be augmented or enhanced to address all the issues. In developing comprehensive remediation alternatives, the project team considered the multiple goals and objectives that must be achieved for an acceptable solution. In particular, comprehensive remediation alternatives were developed to mitigate the release of contaminants to the environment along various exposure or migration pathways.

FIGURE 4-2
DEVELOPMENT OF COMPREHENSIVE REMEDIATION ALTERNATIVES – SCHEMATIC DIAGRAM


Pool of Enhancing Environmental Protection Features
Primary Remediation Methods Pool
Combination of Primary Remediation Methods and Enhancing Protection Features (Includes combination of enhancing protection features amongst themselves.)
Comprehensive Remediation Alternatives (*Long List*)
119548AR0501-E042002002KWO

In addition to developing comprehensive remediation alternatives that just meet the project requirements, our team has also considered augmenting or enhancing these alternatives to provide greater certainty through additional levels of protection. These enhancing environmental protection features were considered as design redundancies or contingencies that provide multiple barriers to contaminant release/migration and serve to increase the level of confidence that an alternative will achieve the project goals.

4.5 Evaluation of Comprehensive Remediation Alternatives

The evaluation process that was developed to select a recommended remediation alternative for the area of the site relied on a qualitative assessment of the comprehensive remediation alternatives. It allowed the evaluation to focus on the alternatives that are most promising to satisfy the closure objectives while avoiding consideration of superfluous alternatives.

Comprehensive remediation alternatives were evaluated using the process illustrated in Figure 4-3. The first step in selecting a recommended remediation alternative was to compare all comprehensive remediation alternatives (the "long list") to a second set of exclusionary criteria identified in Table 4.2 as a screening exercise. This step ensured that the combination of an environmental protection feature with a primary remediation method did not undermine the potential effectiveness of the latter. The exercise led to the construction of a "short list" of comprehensive remediation alternatives from which the recommended remediation alternative was selected. It is important to recognize that while the first set of exclusionary criteria shown in Table 4.1 deals mainly with the evaluation of *methods* which have the potential to form *part* of a comprehensive solution, such as reduction of a component of contaminant load to the environment, the second set of exclusionary criteria shown in Table 4.2 focuses on the screening of *comprehensive solutions* and their ability to achieve an overall reduction of contaminant load from the area.

TABLE 4.2
EXCLUSIONARY CRITERIA – SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Exclusionary Criteria	Considerations	Measure
Effectiveness	Does the comprehensive remediation alternative solve the problem? (i.e. Can it contribute to a significant attenuation of any unacceptable impacts on human health or the environment by way of reducing contaminant loads from the entire Area?)	Yes – The comprehensive remediation alternative has the potential to significantly reduce contaminant loads to the environment. No – The comprehensive remediation alternative does not have the potential to significantly reduce contaminant loads to the environment.
Government Regulations and Guidelines	Does the comprehensive remediation alternative conform to applicable government regulations and guidelines relating to site rehabilitation? (e.g. Guideline for Use at Contaminated Sites, Mining Act and Rehabilitation Guidelines)	Yes – The comprehensive remediation alternative is more likely to conform. No – The comprehensive remediation alternative is less likely to conform.
Design Closure Criteria	Will the comprehensive remediation alternative satisfy design closure criteria pertaining to site specific risk assessment of human health and environmental impacts?	Yes – The comprehensive remediation alternative has the potential to satisfy design criteria. No – The comprehensive remediation alternative has no potential to satisfy design criteria.

The detailed evaluation of the short-listed comprehensive remediation alternatives was completed by comparing them against a series of evaluation criteria that not only reflected the objectives of the project but that also captured the essence of environmental assessment criteria that are commonly applied by the MOE when it is required to evaluate impacts associated with a given project. Appendix A illustrates how the detailed evaluation criteria used in the process described here and the environmental assessment screening criteria are related.

The detailed evaluation criteria consist of four categories of criteria listed below. All criteria carry equal weight in the evaluation process and consequently their order of appearance does not reflect the relative importance of each criterion.

- Technical Considerations
  - Reliability
  - Compatibility with existing system
  - Ease of implementation
- Costs
  - Operation and maintenance costs
  - Capital costs

- Social Considerations
  - Public acceptance
  - Risk to public
  - Constraint for recreational use
  - Negative impact to private properties
  - Visual character of the area
  - Risk to workers

- Natural Environment
  - Geochemistry
  - Terrestrial habitats
  - Floodplain
  - Fish habitats

Table 4.3 summarizes the intent of the detailed evaluation criteria. Further descriptions of each category of criteria are provided below.

TABLE 4.3
DETAILED EVALUATION CRITERIA – COMPREHENSIVE REMEDIATION ALTERNATIVES

Criteria	Considerations	Measure
Technical Considerations		
Reliability	Ability of the alternative to satisfactorily control discharge quality on a regular and reliable basis	Good – very reliable, few performance problems Fair – somewhat reliable, some performance problems Poor – not reliable, many performance problems
Compatibility with Existing System	Ability of the alternative to adapt to the existing site conditions and system	Good – very compatible, few technical problems Fair – somewhat compatible, some technical problems Poor – not compatible, many technical problems
Ease of Implementation	Ability of the alternative to be easily implemented from a technical perspective (e.g. land availability, timing, approval requirements)	Good – easily implemented, few problems Fair – somewhat easily implemented, some problems Poor – not easily implemented many problems encountered
Costs		
Operation & Maintenance Costs	Relative measure of O&M costs compared to other alternatives	High – relatively high operating and maintenance costs Moderate – relatively moderate operating and maintenance costs Low – relatively low operating and maintenance costs
Capital Costs	Relative measure of capital costs compared to other alternatives	High – relatively high capital costs Moderate – relatively moderate capital costs Low – relatively low capital costs
Social Considerations		
Public Acceptance	The potential for the comprehensive remediation alternative to be accepted by the public	High – minimal or no potential for some reservation from the public Moderate – potential for some reservation from the public Low – potential for significant reservation from the public

TABLE 4.3
DETAILED EVALUATION CRITERIA – COMPREHENSIVE REMEDIATION ALTERNATIVES

Criteria	Considerations	Measure
Risk to Public	The potential for the comprehensive remediation alternative to create a risk to public safety	High – potential for significant risk to public safety Moderate - potential for some risk to public safety Low – potential for low/no risk to public safety
Constraint for Recreational Use	The potential for the comprehensive remediation alternative to create constraints for recreational opportunities	High – potential for significant constraints on recreational opportunity Moderate – potential for some constraints on recreational opportunity Low – minimal or no constraints for recreational opportunity
Negative Impact to Private Properties	The potential for the comprehensive remediation alternative to produce a negative impact to private properties	High – potential for significant negative impact to surrounding private properties Moderate – potential for some negative impacts on surrounding private properties Low – minimal or no negative impacts on surrounding private properties
Visual Character of the Area	The potential for the comprehensive remediation alternative to impact the visual character of the area	High – potential to severely impact the visual character of an area Moderate – potential to have some impacts on the visual character of an area Low – minimal impacts on the visual character of an area
Risk to Workers	The potential for the comprehensive remediation alternative to create a risk to workers	High – potential for significant risk to workers Moderate – potential for some risk to workers Low – potential for low/no risk to workers
Natural Environment		
Geochemistry	The potential for the alternative to improve the geochemistry of the area	High – high potential to improve the geochemistry Moderate – some potential to improve the geochemistry Low – low potential to improve the geochemistry
Terrestrial Habitats	The potential of an alternative to improve terrestrial habitats	Good – potential to significantly improve terrestrial habitats Fair – potential to somewhat improve terrestrial habitats Poor – minimal or no improvement to terrestrial habitats
Floodplain	The potential of the alternative to disrupt/intrude upon the floodplain	High – potential to disrupt/intrude upon floodplain resulting in potentially significant impacts to the system. Moderate – potential to cause some disturbance or intrusion into floodplain; impacts less severe Low – minimal/no disturbance; alternative offers the opportunity to "cleanup" floodplain.
Fish Habitats	The potential of the alternative to cause disturbance to or loss of fisheries habitat	High – potential to cause disturbance or loss of significant area of fisheries habitat, significant compensation measures required; Moderate – potential to cause some disturbance or loss of fisheries habitat, some mitigation required; Low – minimal disturbance or no loss of fisheries habitat

4.5.1 Technical Considerations

The first technical criterion dealt with the comprehensive remediation alternative's technical reliability in mitigating human health and environmental impacts from the area. Surface water runoff and/or groundwater discharge have been identified as the main loading sources for the influx of arsenic and metals to the Moira River and Young's Creek. The ability to reduce the contact between the groundwater and the wastes or redirect the groundwater cross flow along with other water inputs to the area also form the basis for the evaluation of the comprehensive remediation alternative's reliability. The ability of the alternative to satisfactorily control discharge on a regular and reliable basis over the long term was considered paramount. These discharges and water inputs can be reduced by selecting or combining some of the following design principles:

- Reducing the amount of precipitation that infiltrates into the impacted materials
- Reducing the amount of groundwater contacting the impacted materials
- Lowering the static groundwater table below the lower horizon of impacted materials
- Intercepting surface water runoff and divert the flow away from the impacted materials
- Minimizing the onsite retention time of any uncontaminated water
- Reducing the contact area of the impacted materials
- Placing the wastes above the water table
- Reducing the rate at which water moves through the wastes

The second criterion examined the comprehensive remediation alternative's ability to operate in tandem with existing systems operating at the site, if present, notably the existing groundwater pumping and arsenic treatment system in the Industrial Area.

Finally, the ease to construct and implement the comprehensive remediation alternative was examined as a precursor to following criteria. Issues such as sufficient workspace, available technologies and complexity were addressed.

4.5.2 Costs

The second category of criteria used for the evaluation of rehabilitation alternatives was costs. Capital, construction, and operation and maintenance costs (O&M) for the comprehensive remediation alternatives were considered relative to each other. Costs were based upon the engineering complexity and work required to implement the alternative.

Costs were estimated on the basis of conceptual remediation plans derived from the conceptual remediation alternatives identified earlier in this process. Budgetary estimates were calculated for this evaluation process and meant to provide an indication of the magnitude of the cost associated with each comprehensive remediation for comparison purposes only. The cost estimates are presented in 2002 dollars.

4.5.3 Social Considerations

Criteria in this category addressed the ability of the remediation alternatives to meet social needs and expectations such as future recreational use of the property, impacts of the works on private property and the overall visual character of the site.

An important step in evaluating the alternatives was the ability to mitigate the threat to human health. The risk to human health was considered for the general public, rehabilitation staff and workers involved in ongoing operation and maintenance of the site, based on the potential for acute and long-term effects.

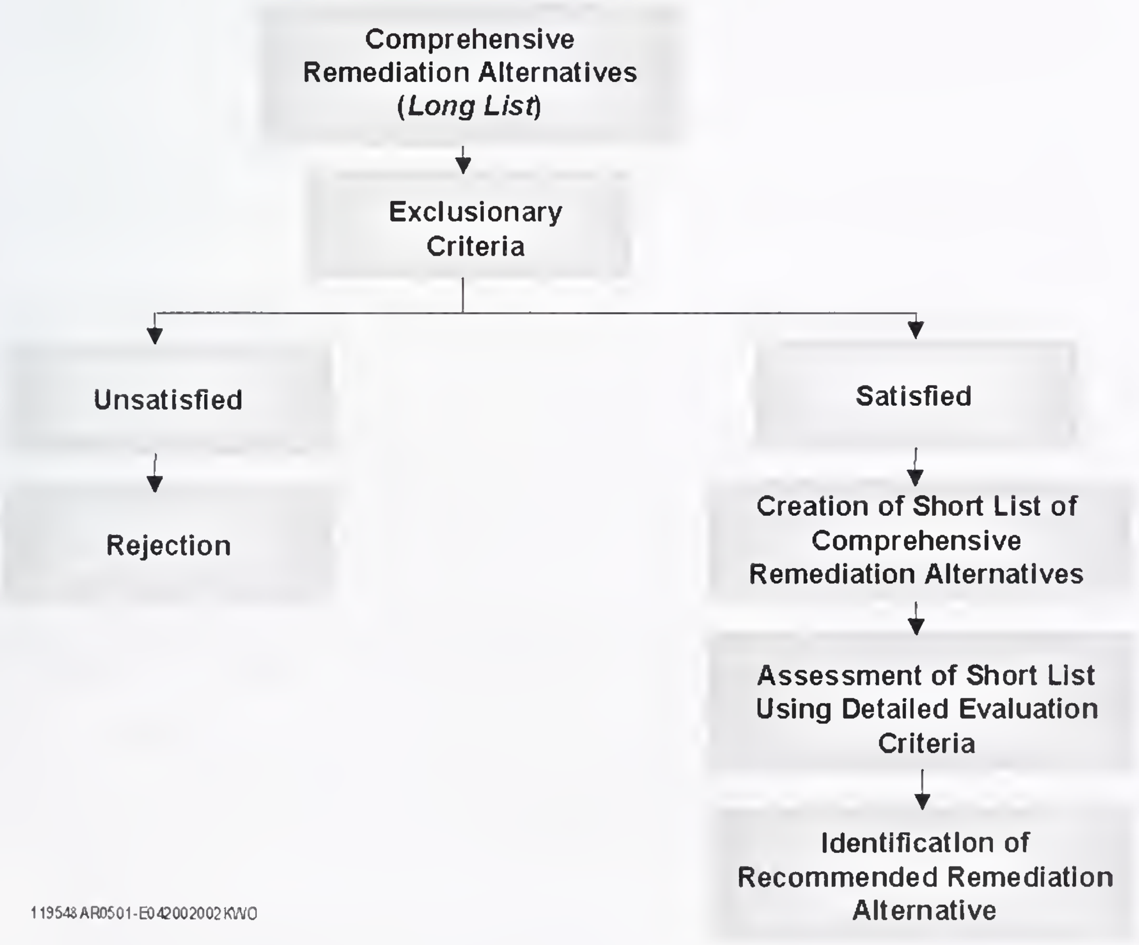
4.5.4 Natural Environment

This category encompasses all of the natural environmental components not covered in the above subsection. This evaluation examined the alternative's ability to improve or protect the following:

- Geochemistry (Surface water and groundwater quality)
- Terrestrial habitats
- Floodplains
- Fish habitats

Figure 4-3 schematically illustrates the process used for the detailed evaluation of the short-listed comprehensive remediation alternatives to determine the recommended remediation alternative.

FIGURE 4-3
EVALUATION OF COMPREHENSIVE REMEDIATION ALTERNATIVES – SCHEMATIC DIAGRAM


Comprehensive Remediation Alternatives (*Long List*)
Exclusionary Criteria
Unsatisfied
Satisfied
Rejection
Creation of Short List of Comprehensive Remediation Alternatives
Assessment of Short List Using Detailed Evaluation Criteria
Identification of Recommended Remediation Alternative
119548AR0501-E042002002KWO

4.6 Summary

The strategic direction of the Deloro Mine Site Cleanup Project in the early 1990s was to manage wastes onsite. Based on the overall project objective, which is to mitigate any unacceptable impacts on human health and the environment, a process was developed to generate "reasonable" comprehensive remediation alternatives for the area. The system relied on the use of exclusionary criteria to identify conceptual remediation alternatives that may be applicable for the area. It also allowed for the development of enhancing environmental protection features that could augment the level of protection offered by any given remediation alternative.

Following the generation of a long list of comprehensive remediation alternatives, each alternative was evaluated against two sets of criteria to identify a recommended remediation alternative. This evaluation of the alternatives against the first set of criteria resulted in a short list of comprehensive remediation alternatives that was evaluated in greater detail using the second set of criteria (i.e. the detailed evaluation criteria). The latter criteria provided a more detailed level of comparison of each alternative with respect to the others and allowed the selection of a recommended remediation alternative for the area.

An alternative was recommended that satisfied the greatest number of criteria and provided the greatest value to MOE based on the professional judgement of the CH2M HILL team.

5. Development and Evaluation of Alternatives

The development and evaluation of remediation alternatives for the Mine Area is driven by the closure objectives discussed in the following section.

5.1 Remedial and Closure Objectives

The overall remedial objectives for the Deloro site are stated in Section 4.2. Area-specific objectives were developed for the Industrial, Tailings, Mine and Young's Creek Areas in the *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a). Closure objectives specific to the Mine Area include:

1. Develop a rehabilitation closure plan supported by a Site Specific Risk Assessment (SSRA)
2. Develop/implement risk reduction plans according to site-wide priorities
3. Consolidate contaminated (heavily impacted) materials into limited areas of the site (where appropriate)
4. Restore closed mine areas to blend in with native conditions (current natural surroundings)

5.2 Identification of Conceptual Remediation Methods

As described in Section 4.3, the first step in the generation of remediation alternatives for the Mine Area consisted of identifying conceptual remediation methods that have been applied in similar situations. The alternatives are intended to provide a method to manage/remediate the specific problems for each issue in the Mine Area as discussed in Sections 2 and 3 of this report. In each case, the "do nothing" method provided a benchmark against which the other remediation methods were assessed.

The conceptual remediation methods that were identified for the Mine Area (i.e. Main Mine Area and Remote Mine Area) are itemized in Table 5.1. Each of the conceptual remediation methods outlined in Table 5.1 is described further in the following sections.

5.2.1 Methods Identified for the Main Mine Area

Conceptual remediation methods identified for the Main Mine Area are presented for each issue within this area. The issues include contaminant load from:

- Waste rock
- Heavily impacted soil and concentrated wastes
- Groundwater discharge from mine workings

Table 5.1
Remedial Methods Identified for Mine Area[1]

Component of Mine Area	Location of Issue/Problem Within Area	Specific Problem (Designation)	Identified Methods
1. Main Mine Area	Gatling/Tuttle Shafts/Red Shaft/Power House	Waste Rock (Main Mine Waste Rock)	1. Do nothing 2. Cover geofabric, clay, topsoil, and then vegetate 3. Excavate, consolidate, and cover with geofabric, clay, topsoil, and then vegetate, restore excavated areas 4. Excavate and bury in existing mine shafts, restore excavated areas
		Heavily Impacted Soil/ Concentrated Wastes (Main Mine Soils)	1. Do nothing 2. Cover entire affected area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 3. Cover only heavily impacted areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 4. Excavate and dispose of heavily impacted soil, restore excavated areas 5. Excavate and bury in existing mine shafts, restore excavated areas
		Groundwater Discharge from mine workings (Main Mine Groundwater)	1. Do nothing 2. Increase pumping from Tuttle Shaft
2. Remote Mine Area	Former Mine Shafts – Hawkeye, 5 Acres, Pearce, Cook's	Waste Rock (Remote Mine Waste Rock)	1. Do nothing 2. Cover with geofabric, clay, topsoil, and then vegetate 3. Excavate, consolidate, and cover with geofabric, clay, topsoil, and then vegetate, restore excavated areas 4. Excavate and bury in existing mine shafts, restore excavated areas
	Undeveloped Areas	Shallow arsenic impacted soils (Remote Mine Soils)	1. Do nothing 2. Excavate and remove for disposal, restore excavated areas 3. Cover with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 4. Excavate and bury in existing mine shafts, restore excavated areas

[1] For the purposes of this evaluation, clay has been identified as the preferred material to use in constructing an engineered earthen cover over wastes and impacted soil. The actual material to be used will be determined in the Closure Plans based on further engineering evaluation, materials availability and cost analysis.

Main Mine Waste Rock

Four remedial methods were identified for waste rock.

- **Do nothing.** This method consists of not modifying current site conditions in any way and would involve no intrusive site work such as excavation or physical movement of waste rock materials. As such, it does not constitute a "genuine" conceptual remediation method. However, the "do nothing" scenario is typically considered in evaluation schemes because it helps determine current site conditions in terms of contaminant release pathways, exposure routes and contaminant loading. It constitutes a baseline against which other conceptual methods can be compared. Since waste rock would remain in an "as is" state, action may be limited to institutional controls such as fencing and signage as determined during the site risk assessment.

- **Cover waste rock with geofabric, clay, topsoil, and then vegetate.** This option would involve the placement of a low permeability soil cover over areas of waste rock. The components of this approach include leveling and regrading waste rock piles to allow for the placement of the geofabric to keep the soil from migrating down through the voids in the rock followed by low permeability clay. This clay cover would be approximately 0.5 m thick or less, as the waste rock is not a primary contributor to groundwater impacts. The clay would be covered by a surficial layer of topsoil and vegetated with grasses, trees, and/or shrubs. The cover design would reduce, but not eliminate, vertical overburden groundwater flow to the clay cover and underlying waste material and would limit human/animal contact. With this option the waste rock is somewhat redistributed as a result of grading but essentially remains in place. Figure 5-1 shows the affected areas and Figure 5-2 shows the proposed cover concept.
- **Excavate, consolidate, and cover waste rock with geofabric, clay, topsoil, and then vegetate, restore excavated areas.** Using this approach, heavy equipment would be used to excavate waste rock piles for consolidation at a central location on the site. This consolidated mass of waste rock would then be covered with a geofabric to keep the soil from migrating down through the voids in the rock. Low permeability clay and then topsoil would be added and the surface vegetated with grasses, trees, and/or shrubs. The cover design would reduce vertical overburden groundwater flow to the clay cover and underlying waste material. For the purposes of this evaluation, it has been assumed that excavated areas will be backfilled with unimpacted fill, then covered with a clay cover. This is a conservative approach and may not be warranted. The design parameters will be refined in the Closure Plan. By consolidating the waste rock at one location, other controls such as a leachate or groundwater interceptor system could be added to the closure plan design, although such controls are not presently anticipated to mitigate environmental impacts. Extensive regrading, trucking of waste rock and backfill activity would be required as part of this solution. Figure 5-3 shows the affected areas and Figure 5-4 shows the proposed fill and cover concept for restoring the excavated areas.
- **Excavate and bury waste rock in existing mine shafts, restore excavated areas.** Using this approach, heavy equipment would be used to excavate waste rock piles for consolidation within the mine shafts on the site. The mine access openings would then be capped with low permeability soil, topsoil, and vegetated with grasses, trees, and shrubs. The cover design would reduce vertical overburden groundwater flow to the clay cover and underlying waste material. After consolidating the waste rock in the mine shafts, other controls such as a leachate or groundwater interceptor system would be required for the closure plan design due to the fractured nature of the underlying bedrock to mitigate environmental impacts. Extensive excavation, regrading, trucking of waste rock, and backfill activity would be required as part of this solution. Access into the mine shafts is restricted since all of the identified shafts have been infilled or the mouths of the shafts

sealed. The capacity of the mine shafts which might be accessed would need to be assessed as it is unknown whether they could accommodate all of the waste rock. Figure 5-3 shows the affected areas and Figure 5-4 shows the proposed fill and cover concept for restoring the excavated areas.

Main Mine Soils

The following five remedial methods were identified to manage the heavily impacted soil and concentrated wastes in the Main Mine Area.

- **Do nothing.** This method consists of not modifying current site conditions in any way and would involve leaving all heavily impacted soils and concentrated wastes in-situ. Weathering and environmental transport of concentrated waste and soil through wind, and surface and groundwater flow would not be mitigated by this method. As such, it does not constitute a "genuine" conceptual remediation method. However, the "do nothing" scenario is typically considered in evaluation schemes because it helps determine current site conditions in terms of contaminant release pathways, exposure routes and contaminant loading. It constitutes a baseline against which other conceptual methods can be compared. Since the waste materials would remain in an "as is" state, action may be limited to institutional controls such as fencing and signage as determined during the site risk assessment.
- **Cover with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate entire affected area.** With this option the entire Main Mine Area in the vicinity of the Tuttle, Gatling, and Red Shafts over an anticipated total area of approximately 2.9 hectares would be covered with armour rock, a geofabric to keep the soil from migrating down through the voids in the rock, followed by low permeability clay. This clay cover would be approximately 0.5 m thick or less, and would be followed by a surficial layer of topsoil and vegetated with grasses, trees, and/or shrubs. The cover design would reduce vertical overburden groundwater flow through the clay cover and underlying waste material. This option would involve clearing and regrading to establish a proper cover thickness, and excavation of the most concentrated waste for isolation and management in the Industrial Area. To apply this option over the entire area would require the removal of several well established second growth areas. Areas of most concentrated and leachable waste include the arsenic dump north of the Gatling Shaft, and the area of "greenish powder" opposite the Red Shaft (CH2M HILL, July 2002). Following the excavation and removal of the concentrated waste the entire area would be covered thereby eliminating direct contact with the waste and minimizing dust generation. Intermediate zones that may not be heavily impacted would also be covered by the cap. Figure 5-5 shows the extent of this cover layer within the limits of the Main Mine Area with some overlap into the Remote Mine Area and Figure 5-6 shows the proposed cover concept.

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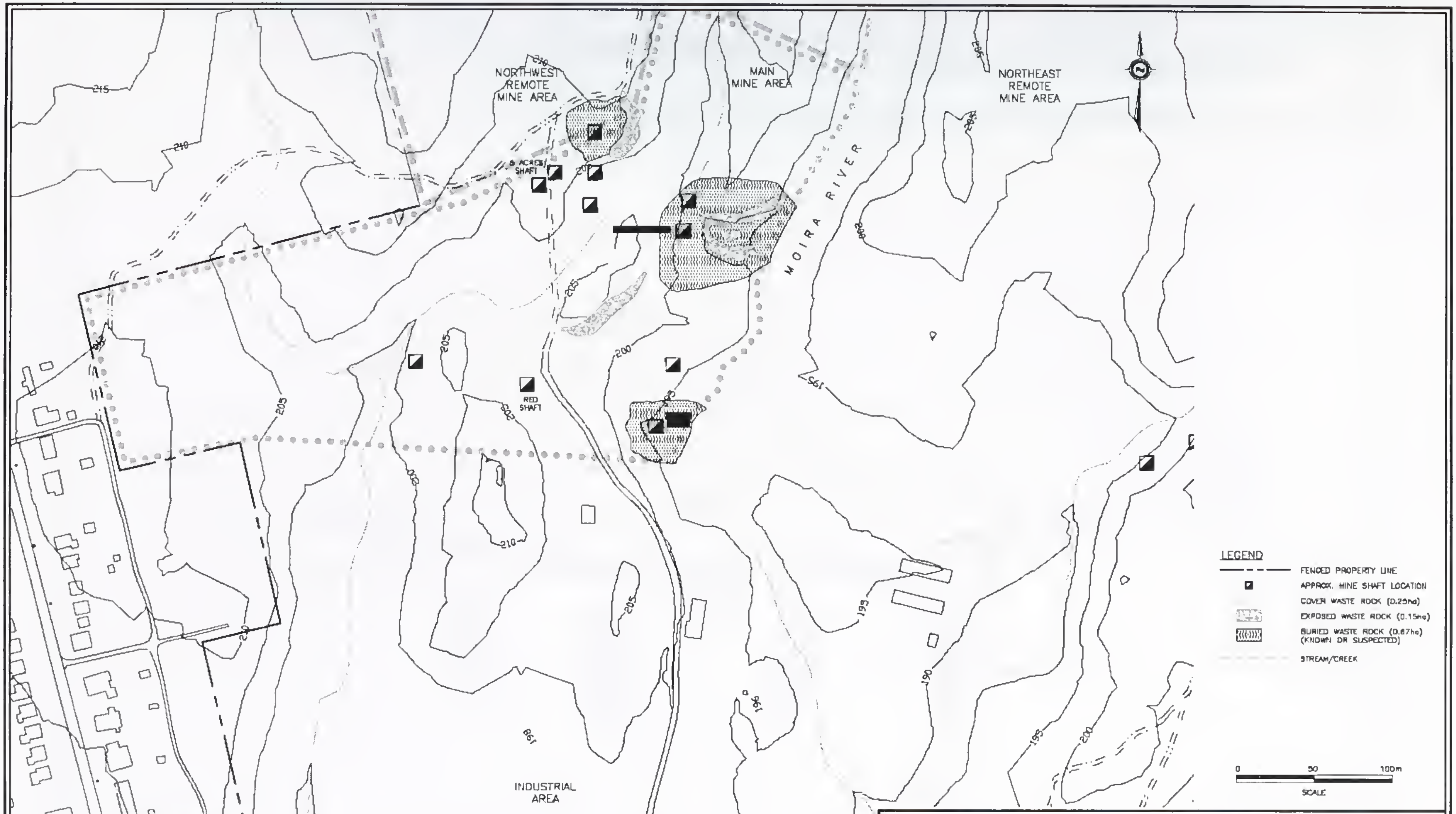
NORTHWEST REMOTE MINE AREA
MAIN MINE AREA
NORTHEAST REMOTE MINE AREA
S ACRES SHAFT
RED SHAFT
MOIRA RIVER
INDUSTRIAL AREA
EQUALIZATION POND
215
210
205
200
195
190
LEGEND
FENCED PROPERTY LINE
APPROX. MINE SHAFT LOCATION
COVER WASTE ROCK (0.25ha)
EXPOSED WASTE ROCK (0.15ha)
BURIED WASTE ROCK (0.87ha) (KNOWN OR SUSPECTED)
STREAM/CREEK
0
50
100m
SCALE

[redacted]

[redacted]

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MAIN MINE WASTE ROCK
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-1
COVER WASTE ROCK WITH GEOFABRIC, CLAY, TOPSOIL, AND THEN VEGETATE

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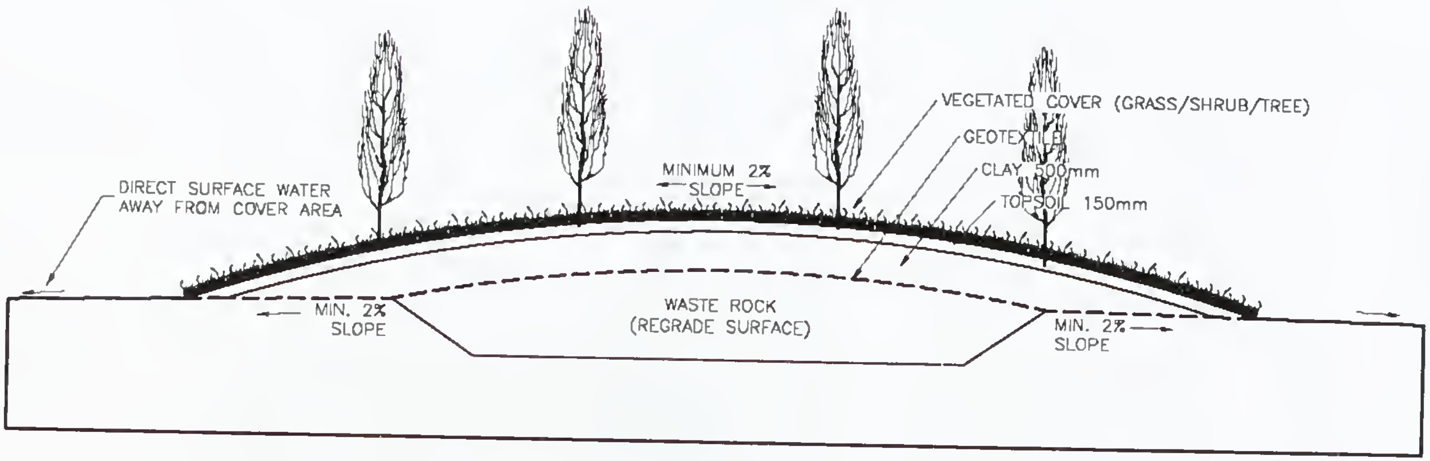
VEGETATED COVER (GRASS/SHRUB/TREE)
GEOTEXTILE
CLAY 500mm
TOPSOIL 150mm
MINIMUM 2% SLOPE
DIRECT SURFACE WATER AWAY FROM COVER AREA
MIN. 2% SLOPE
WASTE ROCK (REGRADE SURFACE)
MIN. 2% SLOPE

NOTE. SURFACE WATER TO BE DIRECTED TO MINIMIZE INFILTRATION POTENTIAL.
N.T.S.

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-2
WASTE ROCK COVER METHOD

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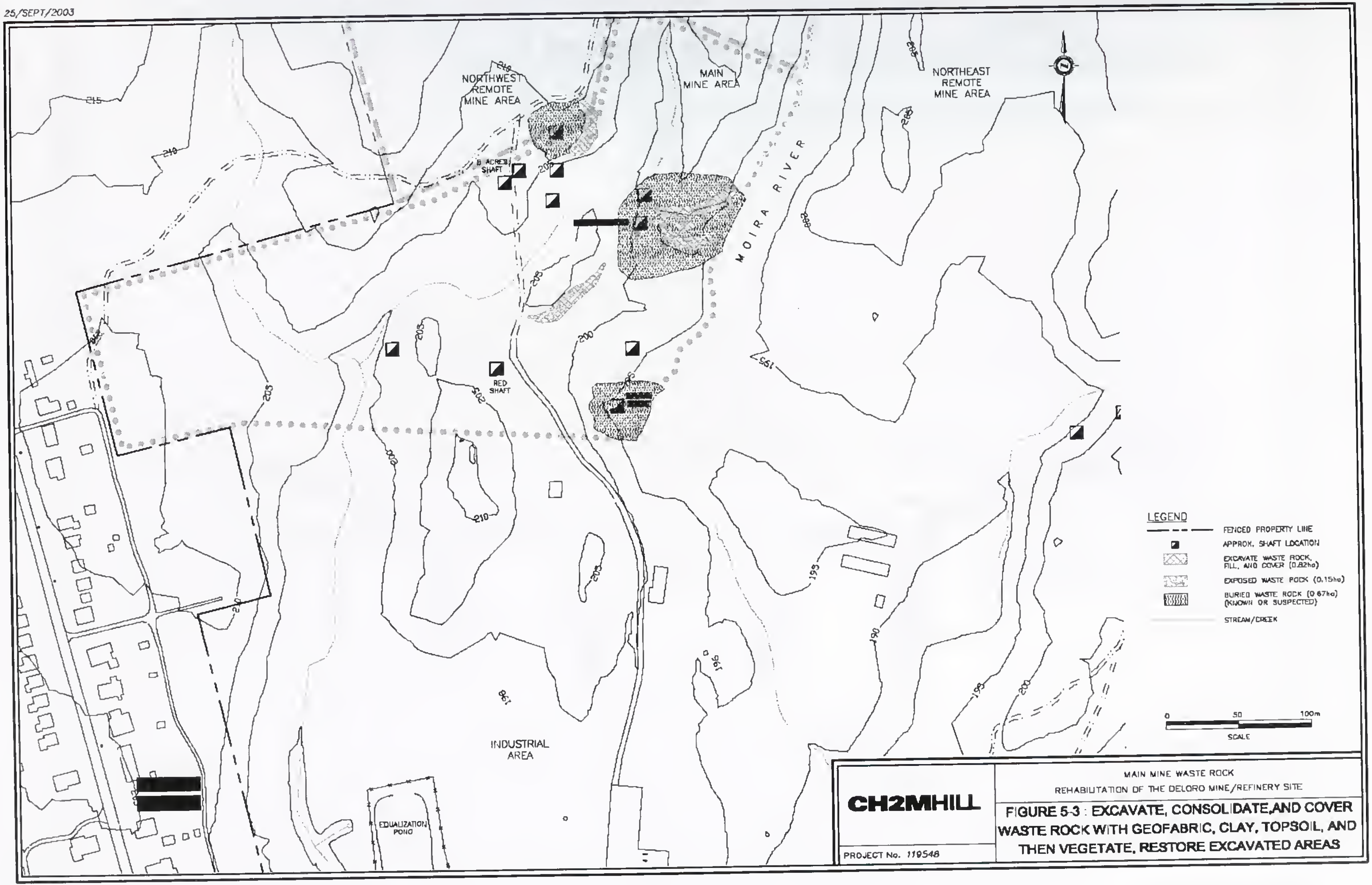

CH2MHILL

MAIN MINE WASTE ROCK
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-3 : EXCAVATE, CONSOLIDATE, AND COVER WASTE ROCK WITH GEOFABRIC, CLAY, TOPSOIL, AND THEN VEGETATE, RESTORE EXCAVATED AREAS

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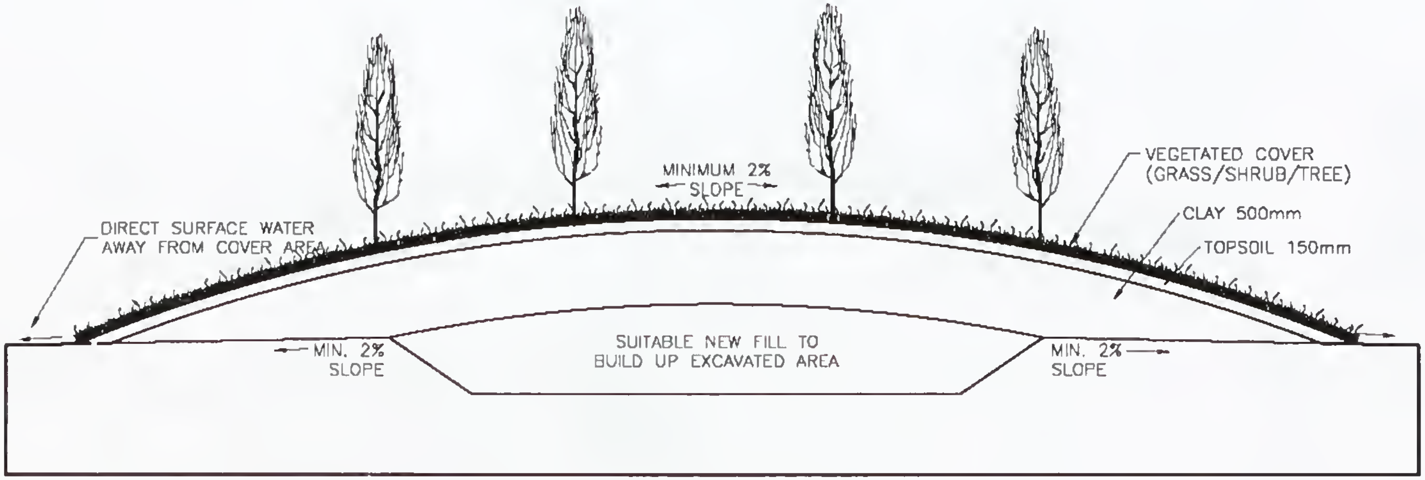

NOTE: SURFACE WATER TO BE DIRECTED TO MINIMIZE INFILTRATION POTENTIAL.
N.T.S

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-4
WASTE ROCK, IMPACTED SOIL AND/OR CONCENTRATED WASTE COVER METHOD - EXCAVATED AREAS

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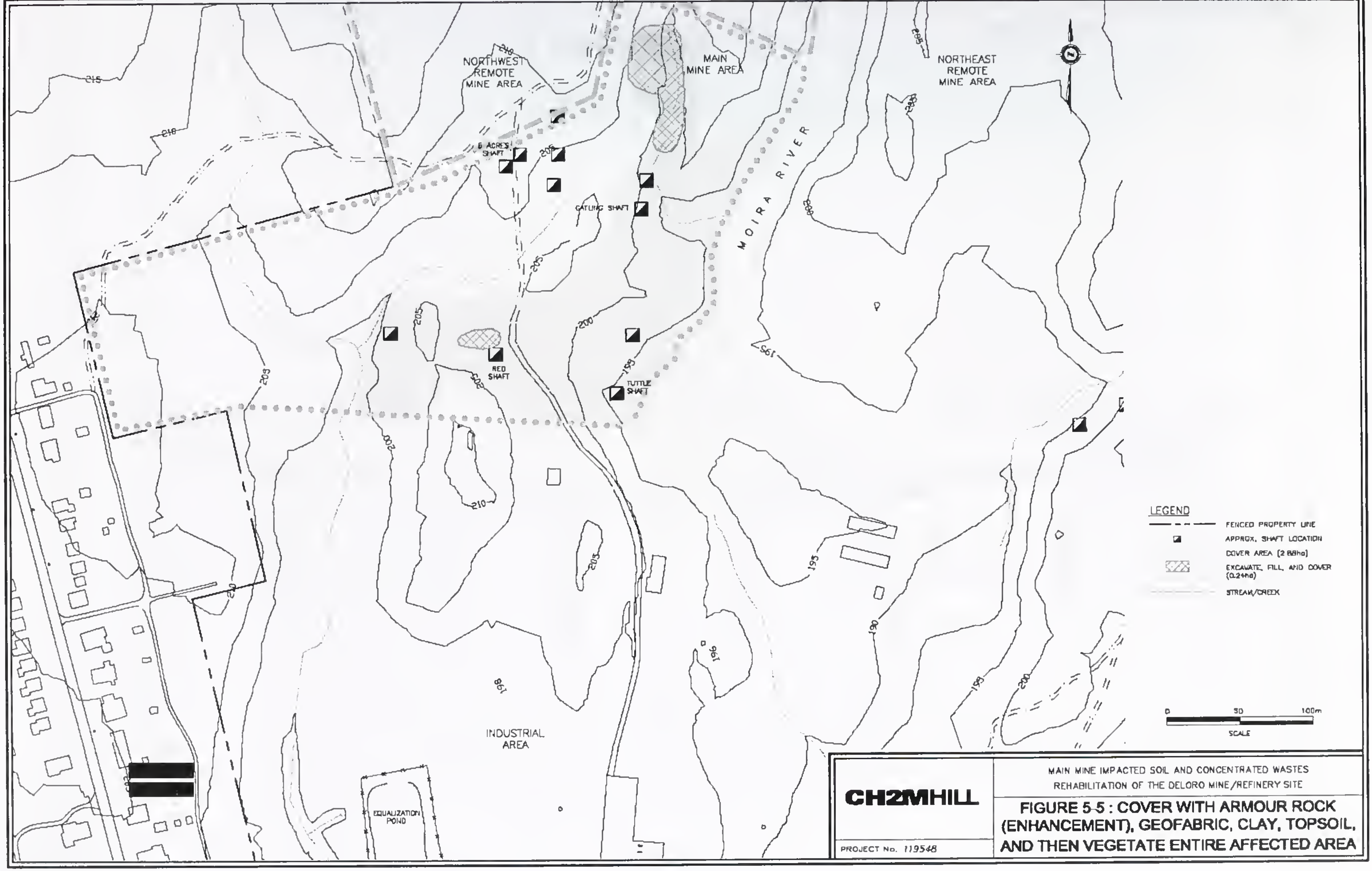

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MAIN MINE IMPACTED SOIL AND CONCENTRATED WASTES
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-5 : COVER WITH ARMOUR ROCK (ENHANCEMENT), GEOFABRIC, CLAY, TOPSOIL, AND THEN VEGETATE ENTIRE AFFECTED AREA

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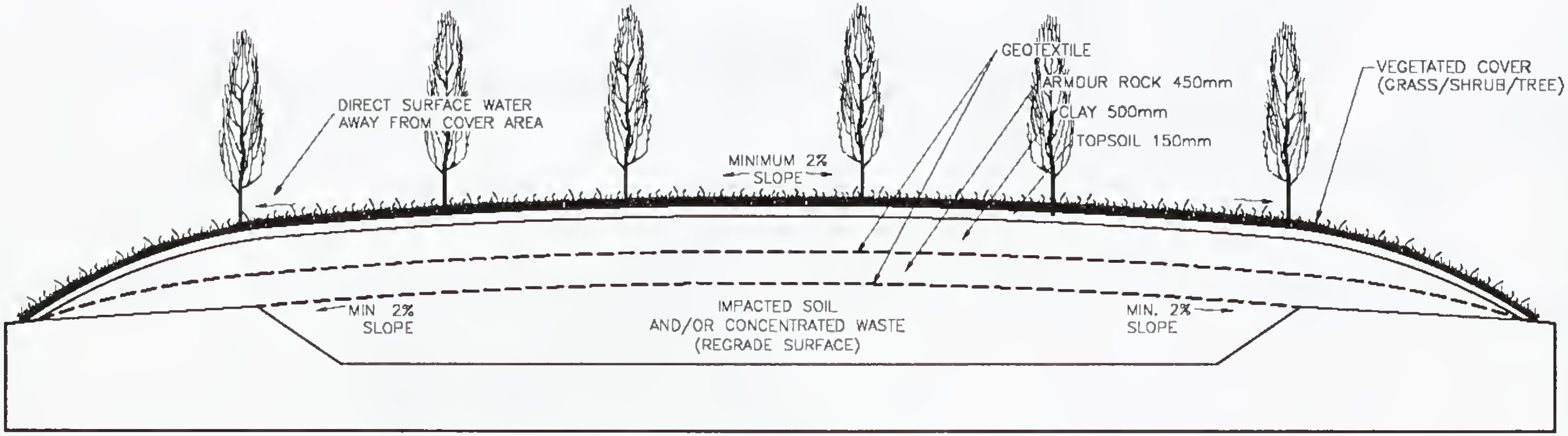
GEOTEXTILE
ARMOUR ROCK 450mm
CLAY 500mm
TOPSOIL 150mm
VEGETATED COVER (GRASS/SHRUB/TREE)
DIRECT SURFACE WATER AWAY FROM COVER AREA
MINIMUM 2% SLOPE
MIN 2% SLOPE
IMPACTED SOIL AND/OR CONCENTRATED WASTE (REGRADE SURFACE)
MIN. 2% SLOPE

NOTE: SURFACE WATER TO BE DIRECTED TO MINIMIZE INFILTRATION POTENTIAL.
N.T.S

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PROJECT No. 119548

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-6
IMPACTED SOIL AND/OR CONCENTRATED WASTE COVER METHOD - NON-EXCAVATED AREAS

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- **Cover with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate heavily impacted areas only.** Using this remedial measure, only heavily impacted zones would be covered with armour rock, capped with a geofabric to keep the soil from migrating down through the voids in the rock, and followed by low permeability clay. This clay cover would be approximately 0.5 m thick or less, and would be followed by a surficial layer of topsoil and vegetated with grasses, trees, and/or shrubs. The exception would be the highly concentrated wastes that would be excavated and managed in the Industrial Area as per the previous method. As a result, intermediate zones that are not heavily impacted would not be covered by cap materials. This method would largely avoid the need to clear second growth forested areas. The cap would therefore be discontinuous across the Main Mine Area. The cover design would reduce vertical overburden groundwater flow to the clay cover and underlying waste material. Figure 5-7 shows the affected areas and Figure 5-6 shows the proposed cover concept.
- **Excavate and dispose of heavily impacted soils, then restore excavated areas.** This approach requires excavating and consolidating all surficial soil and concentrated wastes from an anticipated total area of approximately 2.9 hectares. With this approach, all soils and wastes would be stripped, excavated, and trucked to the Industrial Area for management. Significant regrading and/or placement of suitable fill material and topsoil would be undertaken to promote revegetation of the area. The cover design would reduce vertical overburden groundwater flow through the clay cover and underlying waste material. Dust and direct pathways to heavily impacted soil and mine wastes would be eliminated via contaminant source removal. By using this option it is possible that some non-heavily impacted soils would also be excavated for isolation, unless further delineation of soil is undertaken during the construction stage of the remedial program. Figure 5-8 shows the affected areas and Figure 5-4 shows the proposed fill and cover concept.
- **Excavate selected soils and bury in existing mine shafts, then restore excavated areas.** Using this approach, heavy equipment would be used to excavate selected soils (see Figure 5-9) that are heavily impacted beyond acceptable criteria for consolidation within the mine shafts on the site. The mine access openings would then be capped with low permeability soil, topsoil, and vegetated with grasses, trees, and shrubs. The cover design would reduce vertical overburden groundwater flow to the clay cover and underlying waste material. After consolidating the selected soils in the mine shafts, other controls such as a leachate or groundwater interceptor system would be required for the closure plan design due to the fractured nature of the underlying bedrock to mitigate environmental impacts. Extensive excavation, regrading, trucking of waste rock, and backfill activity would be required as part of this solution. Access into the mine shafts is restricted since all of the identified shafts have been infilled or the mouths of the shafts sealed. The capacity of the mine shafts which might be accessed would need to be assessed as it is unknown whether they could accommodate all of the wastes. Figure 5-4 shows the proposed fill and cover concept.

Main Mine Groundwater

As noted in Section 2, a principal component of arsenic loading to the Moira River is the discharge of deep groundwater that has been contaminated by exposure to mineralized zones in the abandoned mine workings. This discharge to the river occurs through artesian flow from the Tuttle Shaft, and through open bedrock fractures that are hydraulically connected to the river. The following two remedial methods were identified for the contaminated groundwater discharge from the mine workings:

- **Do nothing.** This method consists of not modifying current site conditions or operations in any way and no new measures to control the discharge of contaminated groundwater would be initiated. This approach would result in the continued input of impacted groundwater to the Moira River by way of underground fractures in the bedrock, and by artesian flow and during times when the existing Tuttle Shaft pumping system is inactive. As such, it does not constitute a "genuine" conceptual remediation method. However, the "do nothing" scenario is typically considered in evaluation schemes because it helps determine current site conditions in terms of contaminant release pathways, exposure routes and contaminant loading. It constitutes a baseline against which other conceptual methods can be compared. Since groundwater pumping would remain in an "as is" state, other action would be necessary to achieve the remediation targets established for the site (CG&S, October 1998a).
- **Increase pumping from Tuttle Shaft.** By increasing the pumping of the Tuttle Shaft, the migration of deep groundwater to the Moira River would be reduced, thereby significantly diminishing current arsenic loading rates. This method would require upgrading the current pumping system for year-round operation and directing pumped groundwater to the existing arsenic treatment plant.

5.2.2 Methods Identified for the Remote Mine Area

Conceptual remediation methods identified for the Remote Mine Area are presented for each issue within this area, which include: waste rock present near the former mine shafts (0.37 ha total area) and impacted soil in the Undeveloped Areas.

Remote Mine Waste Rock

Three remedial methods were identified for waste rock in the Remote Mine Area.

- **Do nothing.** As per waste rock found in the Main Mine Area, this method consists of not modifying current site conditions in any way and would involve no intrusive site work such as excavation or physical movement of waste rock materials. As such, it does not constitute a "genuine" conceptual remediation method. However, the "do nothing" scenario is typically considered in evaluation schemes because it helps determine current site conditions in terms of contaminant release pathways, exposure routes and contaminant loading. It constitutes a baseline against which other conceptual methods can be compared. Since waste rock would remain in an "as is" state, action may be limited to institutional controls such as fencing and signage as determined during the site risk assessment.

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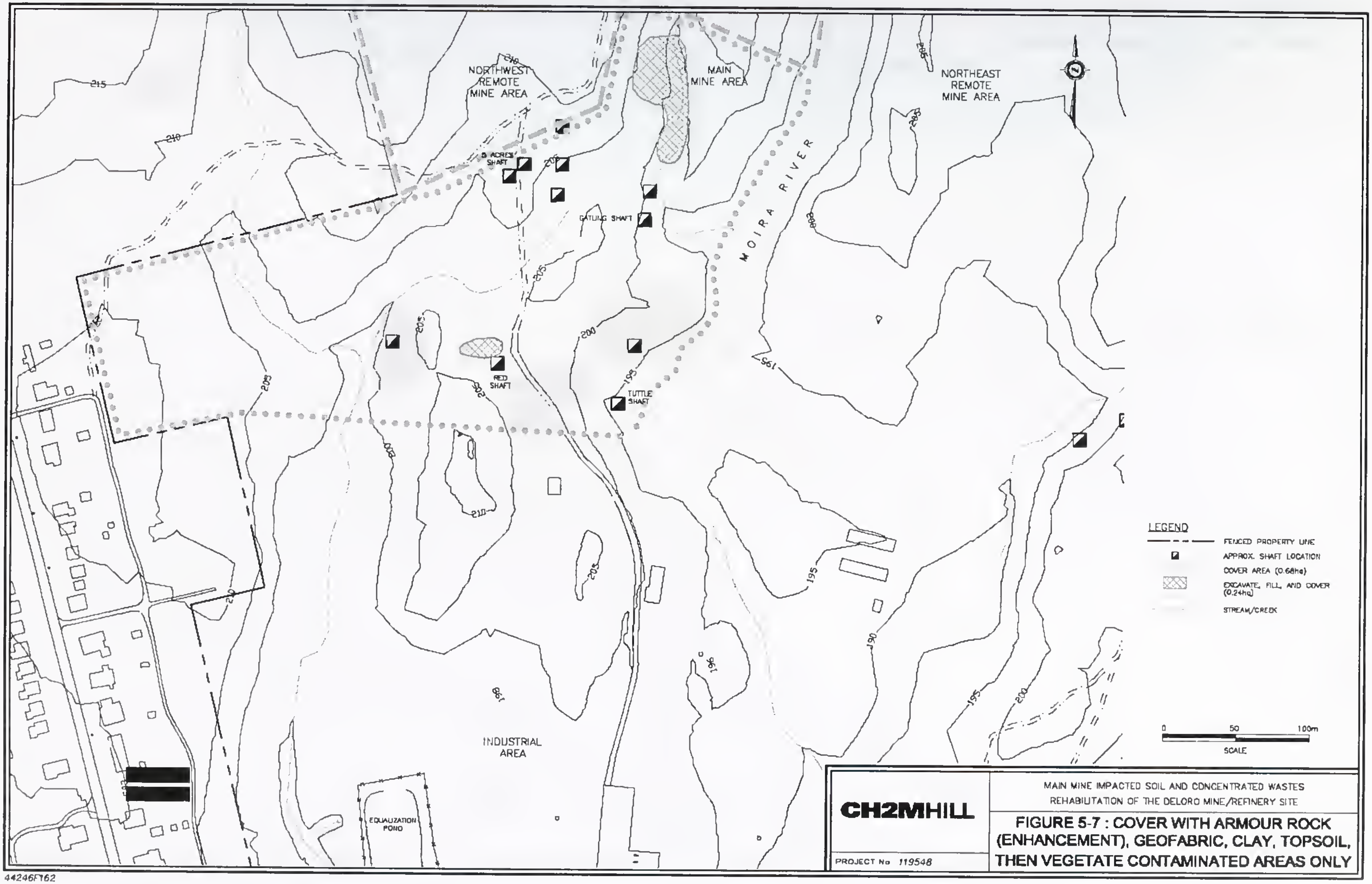

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MAIN MINE IMPACTED SOIL AND CONCENTRATED WASTES
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-7 : COVER WITH ARMOUR ROCK (ENHANCEMENT), GEOFABRIC, CLAY, TOPSOIL, THEN VEGETATE CONTAMINATED AREAS ONLY

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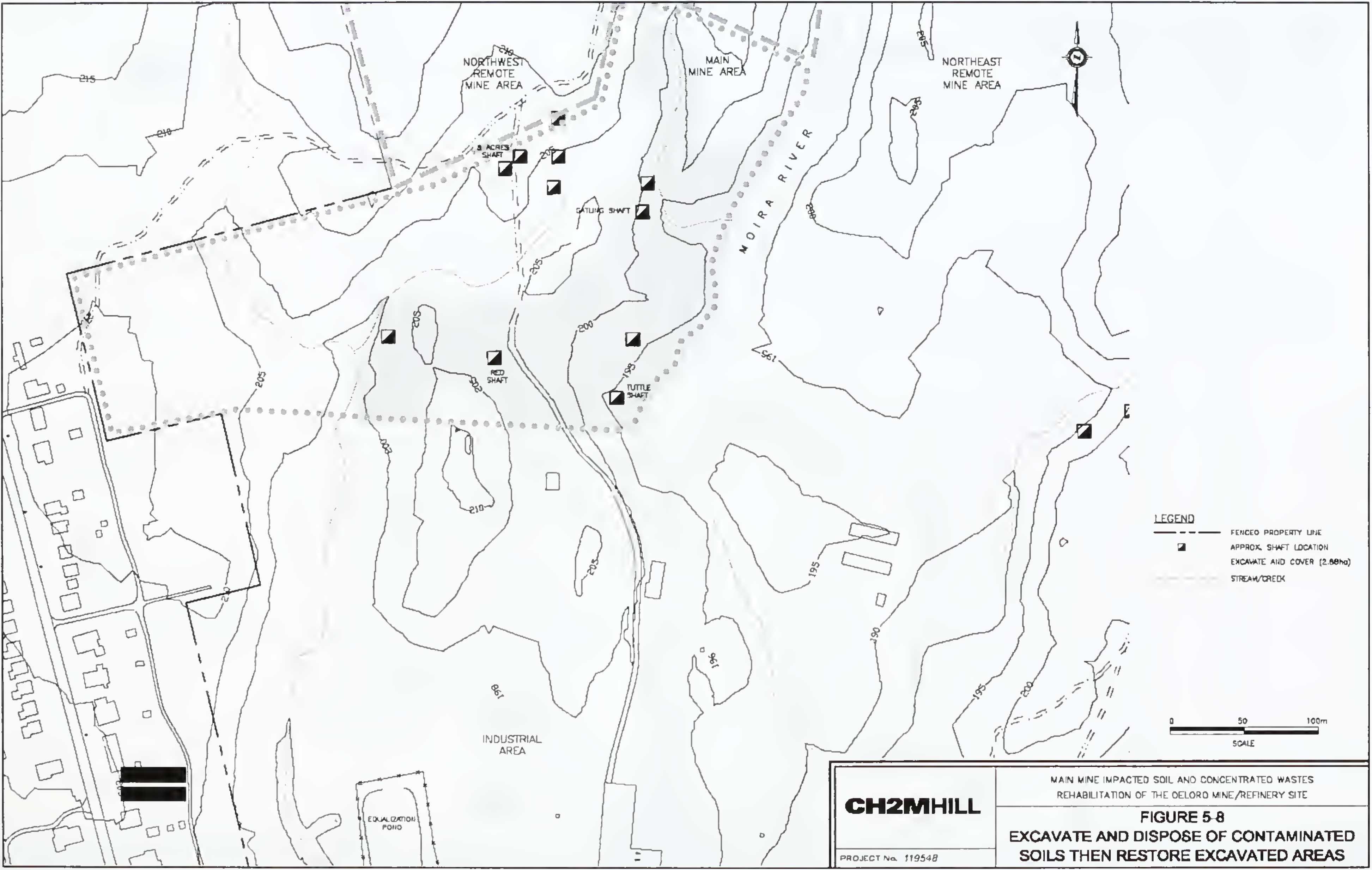

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MAIN MINE IMPACTED SOIL AND CONCENTRATED WASTES
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-8
EXCAVATE AND DISPOSE OF CONTAMINATED SOILS THEN RESTORE EXCAVATED AREAS

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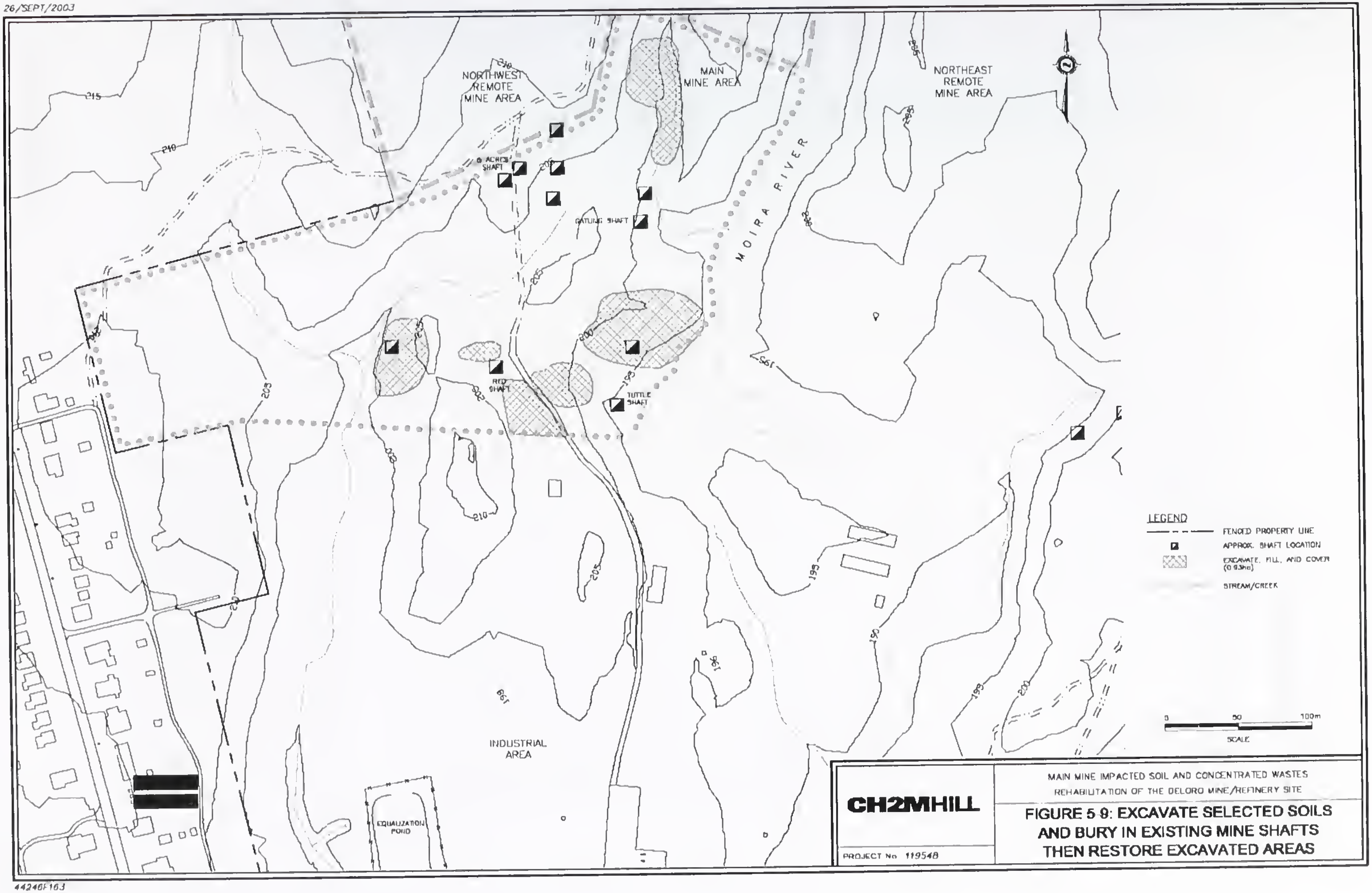

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PROJECT No. 119548

MAIN MINE IMPACTED SOIL AND CONCENTRATED WASTES

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-9: EXCAVATE SELECTED SOILS AND BURY IN EXISTING MINE SHAFTS THEN RESTORE EXCAVATED AREAS

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- **Cover waste rock with geofabric, clay, topsoil, and then vegetate.** This option would involve the placement of a low permeability soil cover over areas of waste rock. The components of this approach include leveling and regrading waste rock piles to allow for the placement of a geofabric to keep the soil from migrating down through the voids in the rock followed by low permeability clay. This clay cover would be approximately 0.5 m thick or less, and would be followed by a surficial layer of topsoil and vegetated with grasses, trees, and/or shrubs. The cover design would reduce vertical overburden groundwater flow to the clay cover and underlying waste material. With this option the waste rock is somewhat redistributed as a result of grading but essentially remains in place.
- **Excavate, consolidate, and cover waste rock with geofabric, clay, topsoil, and then vegetate, restore excavated areas.** Using this approach, heavy equipment would be used to excavate waste rock piles for consolidation at a central location on the site. This consolidated mass of waste rock would then be capped with a geofabric to keep the soil from migrating down through the voids in the rock followed by low permeability clay. This clay cover would be approximately 0.5 m thick or less, and would be followed by a surficial layer of topsoil and vegetated with grasses, trees, and/or shrubs. The cover design would reduce vertical overburden groundwater flow to the clay cover and underlying waste material. By consolidating the waste rock at one location, other controls such as a leachate or groundwater interceptor system could be added to the closure plan design although such controls are not presently anticipated to mitigate the associated environmental impacts. Extensive regrading, trucking of waste rock, and backfill activity would be required as part of this solution.
- **Excavate and bury waste rock in existing mine shafts, then restore excavated areas.** Using this approach, heavy equipment would be used to excavate waste rock piles for consolidation within the mine shafts on the site. The mine access openings would then be covered with a geofabric, capped with low permeability soil and topsoil, and vegetated with grasses, trees, and shrubs. The cover design would reduce vertical overburden groundwater flow to the clay cover and underlying waste material. After consolidating the waste rock in the mine shafts, other controls such as a leachate or groundwater interceptor system would be required for the closure plan design due to the fractured nature of the underlying bedrock to mitigate environmental impacts. Extensive excavation, regrading, trucking of waste rock, and backfill activity would be required as part of this solution. Access into the mine shafts is restricted since all of the identified shafts have been infilled or the mouths of the shafts sealed. The capacity of the mine shafts which might be accessed would need to be assessed as it is unknown whether they could accommodate all of the waste rock.

Remote Mine Soils

Four remedial methods were identified to address the shallow arsenic-impacted soils in the Undeveloped Areas.

- **Do nothing.** This method consists of not modifying current site conditions in any way and would involve leaving all impacted soils in-situ. Only institutional controls (e.g. fencing, signage) would be put in place as part of this solution. Weathering and environmental transport of impacted soil through wind, and surface and groundwater flow would not be mitigated by this method. As such, it does not constitute a "genuine" conceptual remediation method. However, the "do nothing" scenario is typically considered in evaluation schemes because it helps determine current site conditions in terms of contaminant release pathways, exposure routes and contaminant loading. It constitutes a baseline against which other conceptual methods can be compared. Since soils would remain in an "as is" state, action may be limited to institutional controls such as fencing and signage as determined during the site risk assessment.

- **Excavate and remove impacted soils for disposal, restore excavated areas.** Excavating and removing shallow arsenic-impacted soil from the Undeveloped Areas was identified as another possible method. With this approach, all soils would be stripped, excavated, and trucked to the Industrial Area for management. Significant regrading and/or placement of suitable fill material and topsoil would be necessary to promote revegetation as a result of the severe vegetation disturbance caused by excavation equipment. By using this option it is possible that some non-impacted soils would also be excavated for isolation, due to the practical limitations on excavating a thin layer of soil over this extensive area. Detailed delineation of surficial soils could be undertaken during the construction stage of the remedial program to reduce but not eliminate this issue.
- **Cover impacted soils in place with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate.** Using this remedial measure impacted soil would be capped with low permeability soil material. Due to the expansive area involved, intermediate zones of soil that may not be impacted and that pose little human or animal risk would be covered by the soil cap. The cover design would reduce vertical overburden groundwater flow through the clay cover. This method would require clearing of significant tracts of forest to facilitate access for heavy equipment which would result in terrestrial habitat destruction. Such a cap would also require revegetation in order to prevent soil loss due to erosion.
- **Excavate impacted soils and bury in existing mine shafts, then restore excavated areas.** Using this approach, heavy equipment would be used to excavate impacted soils for consolidation within the mine shafts on the site. The mine access openings would then be covered with a geofabric, capped with low permeability soil and topsoil, and vegetated with grasses, trees, and shrubs. The cover design would reduce vertical overburden groundwater flow throughout the clay cover and underlying waste material. After consolidating the impacted soils in the mine shafts, other controls such as a leachate or groundwater interceptor system would be required for the closure plan design due to the fractured nature of the underlying bedrock to mitigate environmental impacts. Extensive excavation, regrading, trucking of impacted soils, and backfill activity would be required as part of this solution. Access into the mine shafts is restricted since all of the identified shafts have been infilled or the mouths of the shafts sealed. The capacity of the mine shafts which might be accessed is likely insufficient for the quantity of the impacted soils.

5.3 Screening of Conceptual Remediation Methods

The second step used in the generation of remedial alternatives was to compare the conceptual remediation methods described above to the set of exclusionary criteria identified in Table 4.1. As explained in Section 4.3, these criteria were designed to eliminate, early in the process, improbable conceptual remediation methods for the area under consideration. From the six conceptual remediation methods listed above (summarized in

Table 5.2), only one satisfied the exclusionary criteria and was retained as the primary remediation method. Table 5.3 details the rationale used to exclude the conceptual methods that were rejected as primary remediation methods.

TABLE 5.2
REMEDIATION METHODS IDENTIFIED FOR MINE AREA

Component of Mine Area	Location of Issue/Problem within Area	Specific Problem (Designation)	Identified Primary Remediation Methods/ Enhancing Environmental Protection Features
1. Main Mine Area	Gatling/Tuttle Shafts/Red Shaft/ Power House	Waste Rock (Main Mine Waste Rock)	1. Cover with geofabric, clay, topsoil, and then vegetate
		Heavily Impacted Soil/ Concentrated Wastes (Main Mine Soils)	1. Cover entire affected area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 2. Cover only heavily impacted areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate 3. Excavate and dispose of heavily impacted soil, restore excavated areas
		Groundwater Discharge from mine workings (Main Mine Groundwater)	1. Increase pumping from Tuttle Shaft to year round (Primary Remediation Method)
2. Remote Mine Area	Former Mine Shafts – Hawkeye, 5 Acres, Pearce, Cook's	Waste Rock (Remote Mine Waste Rock)	1. Cover with geofabric, clay, topsoil, and then vegetate

The primary remediation method that addresses about 55 percent of the loading from this area is:

- Increase Pumping from Tuttle Shaft

There is a large area of relatively low impacted soils throughout the Remote Mine Area. This area would sustain a significant negative environmental impact from clearing and grubbing of large tracts of second growth forest on the property if either covering or excavating and disposing of these soils were to be considered. This area is also considered to be a very small contributor to the total site loading of contaminants and little would be gained by removal and/or capping efforts. At this time, leaving these areas undisturbed is considered to be the environmentally responsible approach and is a component of all alternatives evaluated from this point forward. Confirmation of this assumption will occur with the risk assessment of post-closure conditions prior to implementation, and after all recommended remediation methods for all areas on the site are in place and further monitoring is completed to determine the total load reduction.

Of the conceptual remediation methods that were rejected as primary remediation methods, five showed potential to augment closure performance for the Mine Area if combined with the primary remediation method. These remediation methods form a pool of enhancing environmental protection features that, once combined, are expected to provide a higher level of protection and more closely approach the requirements of the exclusionary criteria.

TABLE 5.3
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary Remediation Method?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Main Mine Waste Rock					
Do nothing	No – Does not mitigate impacts on human heath and the environment	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River will remain unacceptable	No – Main exposure pathways will remain unattenuated	No	No
Cover with geofabric, clay, topsoil, and then vegetate	No – Does not significantly mitigate impacts on the environment	Yes – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced	Yes – Main exposure pathways will be attenuated	No	Yes
Excavate, consolidate, and cover with geofabric, clay, topsoil, and then vegetate, restore excavated areas	No – Does mitigate impacts on human health However, this approach has a negative biological and physical impact since it requires tree removal Excavated areas will require infilling and planting	Yes – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced	No – Although the main exposure pathways will be attenuated upon completion, the potential for improving the site conditions over that of simply covering and vegetating the waste rock is limited	No	No
Excavate and bury in existing mine shafts, restore excavated areas	No – Does not attenuate impacts on the environment Mine entrances will require excavation and transfer into the mine shafts will be risky since their integrity is not known There is also the potential of leakage of surface water and groundwater and it would therefore have no beneficial effects, and could potentially lead to increased contaminant releases to the Moira River	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River may remain unacceptable	No – Main exposure pathways will remain unattenuated or may worsen	No	No
Main Mine Soils					
Do nothing	No – Minimal attenuation of impacts on human health and the environment	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River will remain unacceptable	No – Main exposure pathways will remain unattenuated	No	No

TABLE 5.3
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary Remediation Method?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Cover entire affected area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate	No – Does not significantly mitigate impacts on the environment	No – While discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced, it will come at a significant cost to the existing environment due to excavation of forested and heavily vegetated areas.	Yes – Main exposure pathways will be attenuated	No	Yes
Cover only heavily impacted areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate	No – Does not significantly mitigate impacts on human heath and the environment	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be only slightly reduced	Yes – Main exposure pathways will be attenuated	No	Yes
Excavate and dispose of heavily impacted soils, restore excavated areas	No – Does not significantly mitigate impacts on the environment	No – While discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced, it will come at a significant cost to the existing environment due to excavation of forested and heavily vegetated areas.	Yes – Main exposure pathways will be attenuated	No	Yes
Excavate and bury heavily impacted soils in existing mine shafts, restore excavated areas	No – Does not attenuate impacts on the environment. Mine entrances will require excavation and transfer into the mine shafts will be risky since their integrity is not known There is also the potential of leakage of surface water and groundwater and it would therefore have no beneficial effects, and could potentially lead to increased contaminant releases to the Moira River	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River may remain unacceptable due to leaching from groundwater entering the fractured rock of the mine shafts and from infiltration of rain water through fractures	No – Main exposure pathways will remain unattenuated or may worsen	No	No

TABLE 5.3
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary Remediation Method?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Main Mine Groundwater					
Do nothing	No – Minimal attenuation of impacts on human health and the environment	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River will remain unacceptable	No – Main exposure pathways will remain unattenuated	No	No
Increase pumping from Tuttle Shaft	Yes – Does mitigate impacts on human heath and the environment	Yes – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced	Yes – Main exposure pathways will be attenuated	Yes	N/A
Remote Mine Waste Rock					
Do nothing	No – Minimal attenuation of impacts on human health and the environment	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River will remain unacceptable	No – Main exposure pathways will remain unattenuated	No	No
Cover waste rock piles with geofabric, clay, topsoil, and then vegetate	No – Does not significantly mitigate impacts on the environment	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced minimally	Yes – Main exposure pathways will be attenuated	No	Yes
Excavate, consolidate, and cover waste rock piles with geofabric, clay, topsoil, and then vegetate, restore excavated areas	No – Does mitigate impacts on human health However, this approach has a negative biological and physical impact since it requires creation of access routes to remote areas that will require tree removal Excavated areas will require infilling and planting	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced minimally	No – Although the main exposure pathways will be attenuated upon completion, the potential for improving the site conditions over that of simply covering and vegetating the waste rock is limited	No	No

TABLE 5.3
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary Remediation Method?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Excavate and bury in existing mine shafts, restore excavated areas	No – Does not attenuate impacts on the environment Mine entrances will require excavation and transfer into the mine shafts will be risky since their integrity is not known There is also the potential of leakage of surface water and groundwater and it would therefore have no beneficial effects, and could potetially lead to increased contaminant releases to the Moira River.	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River may remain unacceptable due to leaching from groundwater entering the fractured rock of the mine shafts and from infiltration of rain water through fractures	No – Main exposure pathways will remain unattenuated or may worsen	No	No
Remote Mine Soils					
Do nothing	Yes – Impacts for this area are minimal	Yes – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River will remain acceptable	Yes – Exposure is anticipated to be within acceptable levels	No	Yes
Excavate and remove for disposal, restore excavated areas	No – Does mitigate impacts on human health However, this approach has a significant negative biological and physical impact since it requires creation of access routes to remote areas that will require tree removal in addition to the removal of trees and other vegetation from the large areas being considered for excavation Excavated areas will require infilling and planting	Yes – While the discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced minimally, the contaminant loads will remain acceptable, as identified in the "Do nothing" method	No – Although the main exposure pathways will be attenuated upon completion, the potential for improving site conditions over that of doing nothing is limited	No	No

TABLE 5.3
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary Remediation Method?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Cover in place with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate	No – Does mitigate impacts on human health However, this approach has a significant negative biological and physical impact since it requires creation of access routes to remote areas that will require tree removal in addition to the removal of trees and other vegetation from the large areas being considered for excavation Excavated areas will require infilling and planting	Yes – While the discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River are expected to be reduced minimally, the contaminant loads will remain acceptable, as identified in the "Do nothing" method	No – Although the main exposure pathways will be attenuated upon completion, the potential for improving site conditions over that of doing nothing is limited	No	No
Excavate and bury in existing mine shafts, restore excavated areas	No – Does not attenuate impacts on the environment Mine entrances will require excavation and transfer into the mine shafts will be risky since their integrity is not known There is also the potential of leakage of surface water and groundwater and it would therefore have no beneficial effects, and could potentially lead to increased contaminant releases to the Moira River	No – Discharge of arsenic, cobalt, copper and other contaminant loads to the Moira River may remain unacceptable due to leaching from groundwater entering the fractured rock of the mine shafts and from infiltration of rain water through fractures	No – Main exposure pathways will remain unattenuated or may worsen	No	No

5.4 Development of Comprehensive Remediation Alternatives

The last step in generating the remediation alternatives consisted of combining the primary remediation method with enhancing environmental protection features, where appropriate, to produce three comprehensive remediation alternatives for the Main Mine Area and one for the Remote Mine Area.

The combination of the primary remediation method and the enhancing environmental protection features could have many permutations to generate numerous alternatives. For the purposes of limiting the number of alternatives to the most viable, those generated assumed the following:

- Increased pumping from the Tuttle Shaft was common to all Main Mine Area alternatives
- Excavation and removal of the concentrated wastes was common to all Main Mine Area alternatives
- The existing institutional controls (signs and fencing) for the entire mine site is considered to be sufficient in the interim and requirement for enhancements will be determined as part of the follow-up risk assessment

For the Main Mine Area, the following comprehensive remediation alternatives were generated:

- Increase pumping from Tuttle Shaft; cover entire affected soil/concentrated waste area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate (this includes covering waste rock in the same manner minus the armour rock)
- Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; cover only heavily impacted soil/concentrated waste areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate
- Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; excavate and dispose of heavily impacted soils, cover excavated area with clay, topsoil, and then vegetate

For the Remote Mine Area, the following comprehensive remediation alternative was generated.

- Cover waste rock with geofabric, clay, topsoil, and then vegetate

5.4.1 Screening of Comprehensive Remediation Alternatives

Because all comprehensive remediation alternatives resulted from a combination of primary remediation methods and/or enhancing environmental protection features, they were evaluated against the second set of exclusionary criteria for remediating the entire area, as described in Section 4.5, to ensure that the addition of protection features to the primary remediation methods did not violate the criteria. A summary of whether the comprehensive remediation alternatives did or did not satisfy these criteria is presented in Table 5.4.

TABLE 5.4
SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Comprehensive Remediation Alternative	Exclusionary Criteria			Selected?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria	
1. **Main Mine Area** – Increase pumping from Tuttle Shaft; cover entire affected soil/concentrated waste area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate (this includes covering waste rock in the same manner minus the armour rock) **Remote Mine Area** – Cover waste rock with geofabric, clay, topsoil, and then vegetate	Yes – Contaminant levels are expected to decrease substantially and will be further enhanced after the vegetation is established.	Yes – Contaminant loads will be mitigated immediately when the Tuttle pumping system is put in place and further enhanced as soon as the vegetated cover is established.	Yes – Main exposure pathways will be minimized at the completion of construction	Yes
2. **Main Mine Area** – Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; cover only heavily impacted soil/concentrated waste areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate **Remote Mine Area** – Cover waste rock with geofabric, clay, topsoil, and then vegetate	Yes – Contaminant levels are expected to decrease to below the target discharge levels and will be further enhanced after the vegetation is established.	Yes – Contaminant loads will be mitigated immediately when the Tuttle pumping system is put in place and further enhanced as soon as the vegetated cover is established.	Yes – Main exposure pathways will be minimized at the completion of construction	Yes
3. **Main Mine Area** – Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; excavate and dispose of heavily impacted soils, cover excavated area with clay, topsoil, and then vegetate **Remote Mine Area** – Cover waste rock with geofabric, clay, topsoil, and then vegetate	Yes – Contaminant levels are expected to decrease to below the target discharge levels and will be further enhanced after the vegetation is established.	Yes – Contaminant loads will be mitigated immediately when the Tuttle pumping system is put in place and further enhanced as soon as the vegetated cover is established.	Yes – Main exposure pathways will be minimized at the completion of construction	Yes

5.4.2 Short List of Comprehensive Remediation Alternatives

A detailed description of each comprehensive remediation alternative that satisfied the exclusionary criteria is provided below.

Main Mine Area. *Increase pumping from Tuttle Shaft; cover entire affected soil/concentrated waste area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate (this includes covering waste rock in the same manner minus the armour rock)*

Remote Mine Area. *Cover waste rock with geofabric, clay, topsoil, and then vegetate.*

With this option, by increasing the pumping of the Tuttle Shaft, the migration of deep groundwater to the Moira River would be reduced, thereby significantly diminishing current arsenic loading rates. This would require upgrading the current pumping system for year-round operation, and directing pumped groundwater to the existing arsenic treatment plant. The proposed alignment of the upgraded pipeline is shown on Figure 5-10.

A large portion of the Main Mine Area would be cleared and grubbed and then graded to promote runoff. A layer of armour rock would cover the cleared area with the exception of the waste rock areas and a geofabric would cover the armour rock and the waste rock. A low permeability soil material (i.e. clay) would be used to cover the area and would then be surfaced with a layer of top soil to permit vegetation growth of grasses, trees, and/or shrubs. The extent of this cover layer is shown on Figure 5-10 and the cover methods are presented in Figures 5-2 and 5-6. The cover design would promote runoff through slopes and swales and reduce infiltration and deep percolation to any underlying residual material through evapotranspiration and a low permeability clay layer. This option would involve clearing and regrading to establish a proper cover and excavation of the most concentrated waste for isolation and management in the Industrial Area. Figure 5-4 presents the infilling and cover method for these areas. To apply this option over the entire area would require the removal of several well established second growth areas. Areas of most concentrated waste include the arsenic dump north of the Gatling Shaft and the area of "greenish powder" opposite the Red Shaft (CH2M HILL, July 2002). Following the excavation and removal of the concentrated waste the entire area would be covered thereby eliminating direct contact with the waste and minimizing dust generation. The cap would also cover areas of low impacted soils.

The waste rock areas of the Remote Mine Area would be regraded after access roads were cleared to each area (as required). A geofabric would cover the waste rock and a low permeability soil material (i.e. clay) would be used to cover these selected portions of the Remote Mine Area. The clay cover would be surfaced with a layer of topsoil to permit vegetation growth of grasses, trees, and/or shrubs. The cover design would promote runoff through slopes and swales and reduce infiltration and deep percolation to any underlying residual material through evapotranspiration and a low permeability clay layer. The cover approach can be seen in Figure 5-2.

Main Mine Area. *Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; cover only heavily impacted soil/concentrated waste areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate*

Remote Mine Area. *Cover waste rock with geofabric, clay, topsoil, and then vegetate*

With this option, by increasing the pumping of the Tuttle Shaft, the migration of deep groundwater to the Moira River would be reduced, thereby significantly diminishing current arsenic loading rates. This would require upgrading the current pumping system for year-round operation, and directing pumped groundwater to the existing arsenic treatment plant. The proposed alignment of the upgraded pipeline is shown on Figure 5-11.

Selected areas of the Main Mine Area with impacted soil would be cleared and grubbed. A layer of armour rock would cover the selected heavily impacted soil areas and a geofabric would cover the armour rock and the waste rock. A low permeability soil material (i.e. clay) would be used to cover these selected portions of the Main Mine Area. This clay cover would be surfaced with a layer of topsoil to permit vegetation growth of grasses, trees, and/or shrubs. The cover design would promote runoff through slopes and swales and reduce infiltration and deep percolation to any underlying residual material through evapotranspiration and a low permeability clay layer. The extent of this cover layer is shown in Figure 5-11 and the cover methods are presented in Figures 5-2 and 5-6. This option would involve clearing and regrading to establish a proper cover thickness, and excavation of the most concentrated waste for isolation and management in the Industrial Area. To apply this option over selected areas would require the removal of small well established second growth areas. Areas of most concentrated waste include the arsenic dump north of the Gatling Shaft, and the area of "greenish powder" opposite the Red Shaft (CH2M HILL, July 2002). Following the excavation and removal of the concentrated waste the affected areas would be covered thereby eliminating direct contact with the waste and minimizing dust generation. Infilling and covering methods for the excavated areas is presented in Figure 5-4.

The waste rock areas of the Remote Mine Area would be regraded after access roads were cleared to each area (as required). A geofabric would cover the waste rock and a low permeability soil material (i.e. clay) would be used to cover these selected portions of the Remote Mine Area. The clay cover would be surfaced with a layer of topsoil to permit vegetation growth of grasses, trees, and/or shrubs. The cover design would promote runoff through slopes and swales and reduce infiltration and deep percolation to any underlying residual material through evapotranspiration and a low permeability clay layer. Figure 5-2 presents the cover method for the waste rock.

Main Mine Area. *Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; excavate and dispose of heavily impacted soils, cover excavated area with clay, topsoil, and then vegetate*

Remote Mine Area. *Cover waste rock with geofabric, clay, topsoil, and then vegetate*

With this option, by increasing the pumping of the Tuttle Shaft, the migration of deep groundwater to the Moira River would be reduced thereby significantly diminishing current arsenic loading rates. This would require upgrading the current pumping system for year-round operation, and directing pumped groundwater to the existing arsenic treatment plant. The proposed alignment of the upgraded pipeline is shown on Figure 5-12.

Selected portions of the Main Mine Area would be cleared and grubbed of all vegetation. Heavily impacted soils would be excavated for isolation and management in the Industrial Area. Excavated areas would be infilled to existing grade and capped with clay, topsoil and then vegetated. A geofabric would cover the waste rock and this too would be covered with clay, topsoil, and then vegetated with grasses, trees, and/or shrubs. The cover design would promote runoff through slopes and swales and reduce infiltration and deep percolation to any underlying residual material through evapotranspiration and a low permeability clay layer. This option would also involve excavation of the most concentrated waste for isolation and management in the Industrial Area. Areas of most concentrated waste include the arsenic dump north of the Gatling Shaft, and the area of "greenish powder" opposite the Red Shaft (CH2M HILL, July 2002). Figure 5-12 presents the area affected by this alternative. Infilling and covering methods for the excavated areas is presented in Figure 5-4.

The waste rock areas of the Remote Mine Area would be regraded after access roads were cleared to each area (as required). A geofabric would cover the waste rock and a low permeability soil material (i.e. clay) would be used to cover these selected portions of the Remote Mine Area. The clay cover would be surfaced with a layer of topsoil to permit vegetation growth of grasses, trees, and/or shrubs. The cover design would promote runoff through slopes and swales and reduce infiltration and deep percolation to any underlying residual material through evapotranspiration and a low permeability clay layer. Figure 5-2 presents the cover method for the waste rock.

Each of the above alternatives contains components that are described earlier as conceptual remediation methods. While these descriptions will not be repeated, advantages and considerations will be discussed.

Each short-listed comprehensive remediation alternative is evaluated in the following section.

5.4.3 Detailed Evaluation of Short-Listed Alternatives

As explained in Section 4.5, the three identified short-listed alternatives were compared to a set of detailed evaluation criteria that are designed to select a recommended remediation alternative. Table 5.5 summarizes the results of the evaluation process, while details are provided below.

Technical Considerations

Reliability. This criterion evaluates the ability of the alternative to satisfactorily control the discharge of arsenic and other contaminants to the Moira River. All alternatives are evaluated to provide good control of arsenic discharge to the environment as they combine several control features to minimize contaminant loading. Covering only the heavily impacted soils is somewhat less reliable than other alternatives. The increase in pumping from the Tuttle Shaft provides the greatest contaminant reduction for each alternative and as long as the pump system is well maintained, the contaminant loads from this source will remain low. The reliability of each of the alternatives increase with the number of environmental protection features added on to the primary remediation method. It should be noted that although the Main Mine Area was identified as a main contributor of arsenic to the environment, full achievement of the PWQO for that element at the intersection of the Moira River and Highway 7 will require controlling arsenic releases from other portions of the Deloro Mine Site as well.

Compatibility with Existing System. All short-listed comprehensive remediation alternatives are estimated in the long term to be compatible with the existing site conditions. Planting of trees will accelerate succession of the impacted area to forest. The alternative that involves construction of a soil cover over the majority of the Main Mine Area will require considerable clearing and grubbing of second growth forest and has fair compatibility in the short term. This area will require at least a decade to blend in with the adjacent forested area.

Ease of Implementation. The alternative that involves construction of a soil cover over the majority of the Main Mine Area will require considerable clearing and grubbing of second growth forest, placement of armour rock, and will require large quantities of clay for the capping material. This alternative will, comparatively, have a fair ease of implementation. The alternative that recommends covering highly impacted soil areas with limited excavation is considered to have good ease of implementation. The alternative that recommends excavation of highly impacted soils will require some clearing and grubbing, excavation in an area of former mine workings and waste disposal. Disposal of excavated materials, and infilling is considered to have poor ease of implementation.

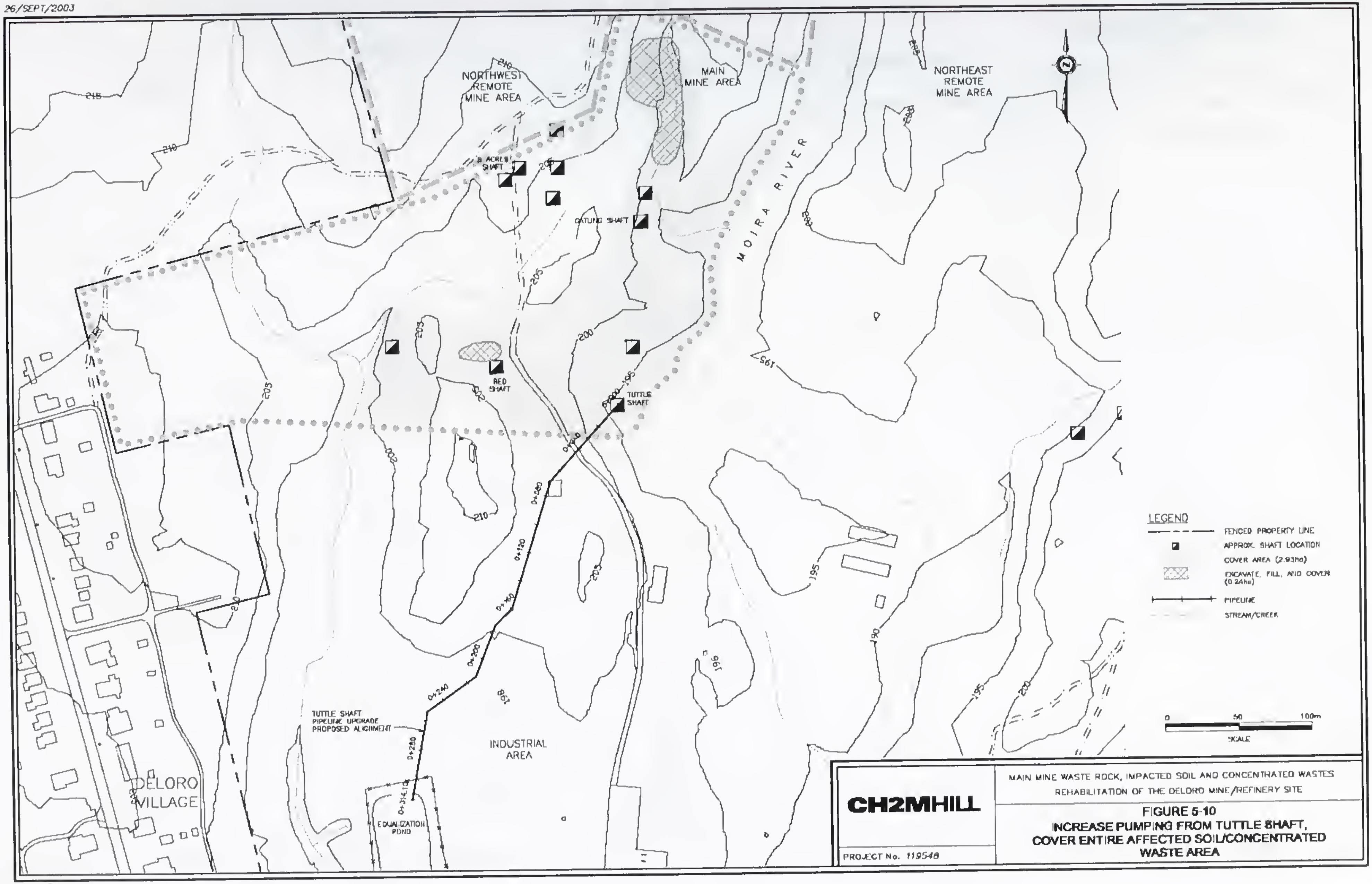
Costs

The capital and construction costs, the annual operation and maintenance costs, and the net present value costs associated with each alternative are summarized in Table 5.5. The breakdown of various components of the total cost associated with each alternative is detailed in Appendix B. In addition, the major assumptions used in the cost opinions are also stated in Appendix B. Because of the uncertainty in design requirements at this conceptual design stage, all costs provided should be considered as "cost opinions" at this stage to assist the MOE in selecting between comprehensive remediation alternatives.

The capital costs associated with the construction of the three comprehensive remediation alternatives varies from $660,000 for the second alternative to $1,120,000 for the first alternative, as described in Section 5.4. The third alternative includes the excavation of selected heavily impacted soils and consolidation of these soils in the Industrial Area. The capacity of the containment cell, its configuration and design components are difficult to estimate at this time, as a rehabilitation alternative has not yet been chosen. No allowance has been included in the costs for the third alternative for modifications or additional earthwork related to adapting the new cell in the Industrial Area for the additional material from the Mine Area.

Annual operation and maintenance (O&M) costs for each of the alternatives were estimated at $10,500. All of the alternatives include increased pumping from the Tuttle Shaft. This will result in an increase in the amount of arsenic laden water to be treated at the arsenic treatment plant located in the Industrial Area. Rehabilitation alternatives developed for the Industrial Area are expected to reduce the inputs from this area to the treatment plant. It is difficult to estimate the net surplus or deficit of water to be treated for the overall Deloro Mine Site. An allowance has been made in the O&M costs for the Industrial Area for the yearly operation of the treatment plant since the plant is located in that area. Therefore, there is no allowance for additional treatment costs included in any of the alternatives in this report. The net present value of the annual O&M costs was $140,000.

26/SEPT/2003



CH2MHILL

MAIN MINE WASTE ROCK, IMPACTED SOIL AND CONCENTRATED WASTES
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-10
INCREASE PUMPING FROM TUTTLE SHAFT, COVER ENTIRE AFFECTED SOIL/CONCENTRATED WASTE AREA

PROJECT No. 119548

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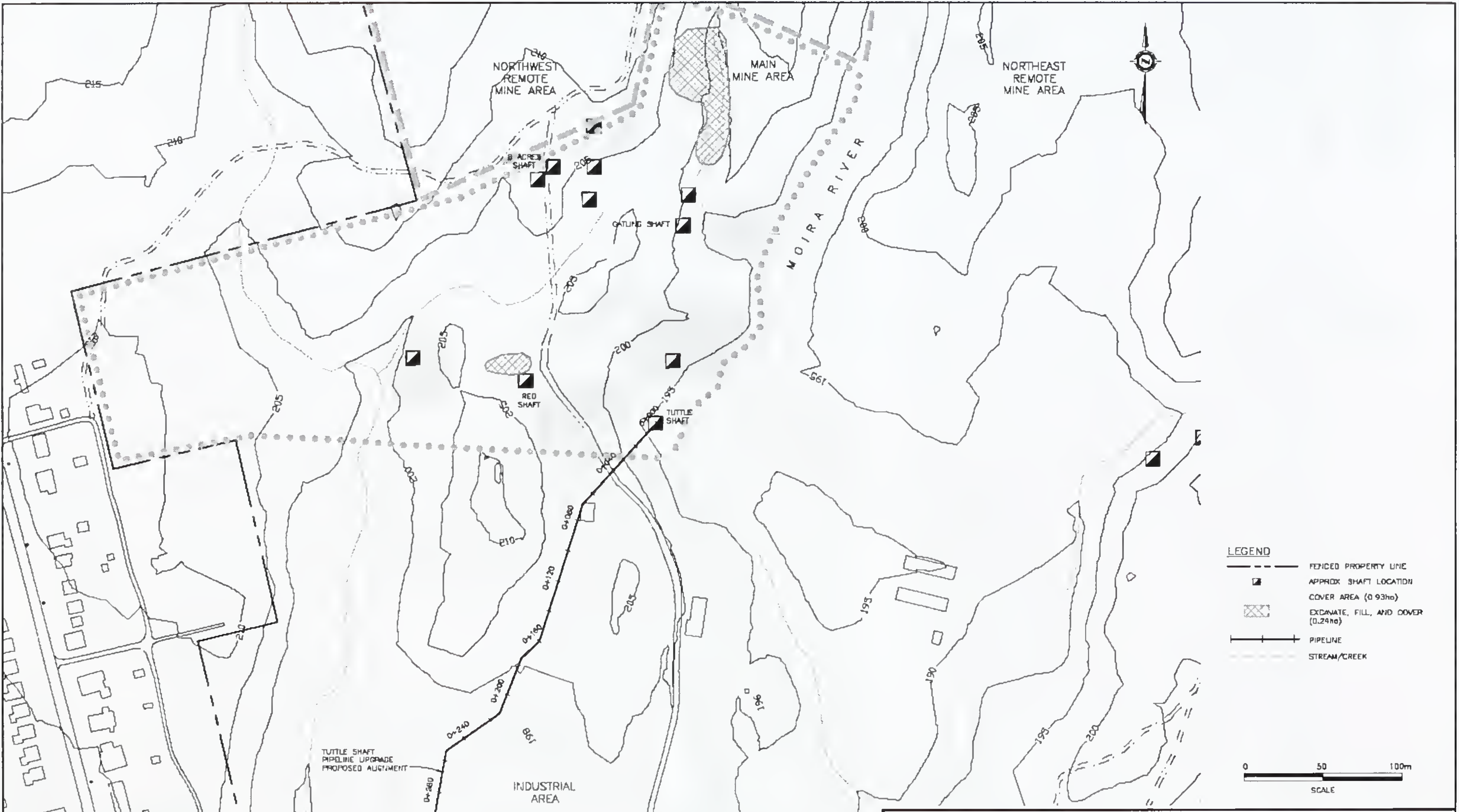

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MAIN MINE WASTE ROCK, IMPACTED SOIL AND CONCENTRATED WASTES
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 8-11:
INCREASE PUMPING FROM TUTTLE SHAFT;
COVER WASTE ROCK, COVER ONLY HEAVILY IMPACTED
SOIL/CONCENTRATED WASTE AREAS

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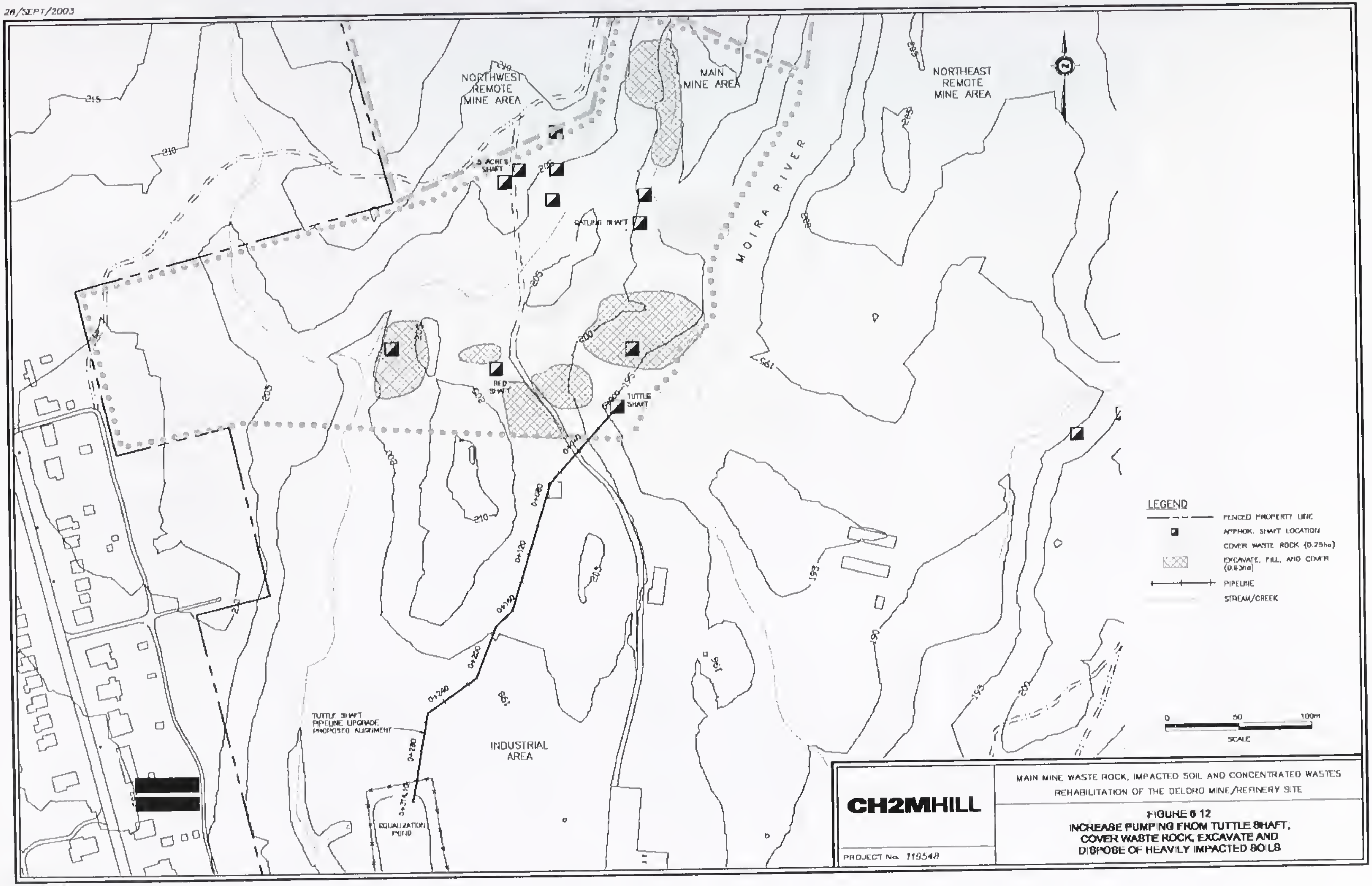

CH2MHILL

PROJECT No. 119548

MAIN MINE WASTE ROCK, IMPACTED SOIL AND CONCENTRATED WASTES
REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 6 12
INCREASE PUMPING FROM TUTTLE SHAFT;
COVER WASTE ROCK, EXCAVATE AND
DISPOSE OF HEAVILY IMPACTED SOILS

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TABLE 5.5
EVALUATION OF SHORT-LISTED COMPREHENSIVE REMEDIATION ALTERNATIVES

Short-Listed Comprehensive Remediation Alternatives	Detailed Evaluation Criteria															
	Technical Considerations			Costs[1]			Social Considerations						Natural Environment			
	Reliability	Compatibility with Existing System	Ease of Implementation	Annual O&M Costs	Capital Costs (millions)	Net Present Value Costs[2] (millions)	Public Acceptance (Level of Reservation)	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character (Impact)	Risk to Workers (Health and Safety)	Geochemistry (Improvement)	Terrestrial Habitats (Improvement)	Floodplain (Infringement)	Fish Habitats (Disruption)
Main Mine Area Increase pumping from Tuttle Shaft, cover entire affected soil/concentrated waste area with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate (this includes covering waste rock in the same manner minus the armour rock) Remote Mine Area Cover waste rock with geofabric, clay, topsoil, and then vegetate	Good	Fair	Fair	$10,500	$1.12	$1.26	Low	Low	Low	Low	Low	Low	High	Fair	Low	Low
Main Mine Area Increase pumping from Tuttle Shaft, cover waste rock with geofabric, clay, topsoil, and then vegetate cover only heavily impacted soil/concentrated waste areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate Remote Mine Area Cover waste rock with geofabric, clay, topsoil, and then vegetate	Fair	Good	Good	$10,500	$0.66	$0.80	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Low	Low
Main Mine Area Increase pumping from Tuttle Shaft, cover waste rock with geofabric, clay, topsoil, and then vegetate, excavate and dispose of heavily impacted soils, cover excavated area with clay topsoil, and then vegetate Remote Mine Area Cover waste rock with geofabric, clay, topsoil, and then vegetate	Good	Good	Poor	$10,500	$1.00	$1.20	Low	Low	Low	Low	Moderate	Moderate	High	Moderate	Low	Low

Notes

[1] Costs include GST and a 15% contingency (before taxes, overhead, insurance and bonds)

[2] Net present value cost assumed an effective interest rate of 5% and a time horizon of 20 years

See Appendix B for more detailed cost breakdown including overhead, insurance and bonds cost estimates

Expected cost accuracy is +50/-30%

The net present value calculations were based on an assumed effective interest rate of five percent and a planning horizon of 20 years. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

Social Considerations

Public Acceptance. All comprehensive remediation alternatives are likely to receive a reasonable degree of public acceptance as the proposed alternatives deal with onsite containment of the most impacted materials, limited (if any) handling of the Mine Area materials and significant reduction of contaminant loads to the environment. Furthermore, the general appearance of the Mine Area will be significantly improved when compared to the current state of the Area. The use of a tree rather than a grass cover will more closely reflect the current surrounding environment and may be seen as more acceptable by the public.

Risk to Public. Because all comprehensive remediation alternatives involve little handling of contaminants and the Deloro Mine Site is effectively restricted to public access, the risk to public health and safety is estimated to be low for all alternatives.

Constraint for Recreational Use. The potential for all of the comprehensive remediation alternatives to have an impact on recreational activities is low since the Deloro Mine Site is not accessible to the public with the exception of the Moira River upstream of the site. While travel is restricted due to an upstream functional dam and a partial dam onsite, the Moira River is used on occasion by canoeists during higher water periods. The proposed remediation alternatives will have no impact on this current use. Should the recreational use change in the years to come, the mining materials will effectively be isolated by armour rock and an engineered soil cover and will consequently not be accessible to the public. The root system of a tree cover will reduce potential for access to the highly impacted soils even further.

Negative Impact to Private Properties. All comprehensive remediation alternatives are anticipated to have minimal impact on private properties as the parts of the Mine Area most affected by the proposed remediation methods are located in the central portion of the Deloro Mine Site. It is anticipated that when soil and aggregates are brought onsite, measures will be implemented to minimize disturbances caused by vehicular traffic (e.g. trucking hours, use of tarps on trucks to minimize dust generation, truck washing station at the exit of the site, sweeping the road used by trucks to haul aggregates, as required, and compliance with municipal by-laws governing noise and construction site activity times).

Visual Character of the Area. All of the comprehensive remediation alternatives will result in a significant improvement to the visual character of the Mine Area, as a vegetated soil cover will cover the waste rock areas. Again, a tree cover will be more in keeping with the adjacent forested areas. A moderate impact will occur for the excavation alternative, as these wastes will be relocated to the Industrial Area.

Risk to Workers. As most of the work in the Mine Area will involve the transportation and grading of earthen materials and little handling of mining byproduct material, the health and safety risk to workers is expected to be low (i.e. similar to the risks associated with large earth moving works, such as heavy machinery hazards). The alternative involving excavation of heavily impacted soil has a moderate risk.

Natural Environment

Geochemistry. Because all comprehensive remediation alternatives minimize infiltration of surface water and the release of impacted water to the Moira River, they are all anticipated to significantly improve the quality of surface and groundwater emanating from the Mine Area. The alternative involving covering of only heavily impacted areas is considered to have only a moderate potential to improve geochemistry.

Terrestrial Habitats The alternative that involves clearing and covering of a large portion of the Main Mine Area will have a negative effect on habitat in the short term due to the extensive earthworks required but will recover over time if designed and constructed correctly. The other two alternatives considered will result in an improvement to terrestrial habitats of the Mine Area by the implementation of a vegetated engineered soil and vegetation cover, especially in the waste rock areas.

Floodplain. Work conducted in the Mine Area will not infringe upon the floodplain.

Fish Habitats. As none of the comprehensive remediation alternatives involve work in a watercourse, the potential of the alternatives to impact fish habitats adjacent to or downstream of the Mine Area is minimal. However, runoff and sediment control measures will need to be implemented during the construction of the selected remediation alternative for the Mine Area.

5.4.4 Selection of Recommended Remediation Alternative

In light of the information presented above, one factor stands out as contributing the most to the reduction of arsenic loading to the environment. It is the increased pumping from the Tuttle Shaft. This is common to all of the alternatives and will not be the determining factor for choosing the most appropriate alternative. While all approaches will provide similar contaminant reduction potential, they vary widely in the extent to which they will impact the existing habitat conditions. The impacts in the Main Mine Area range from very invasive to minimally invasive and will require consideration in determining the most appropriate action. Based on that factor, the comprehensive remediation alternative that is expected to be most effective in reducing infiltration and mitigating discharge from the Mine Area is:

- **Main Mine Area:** *Increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; cover only heavily impacted soil/concentrated waste areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate*
- **Remote Mine Area:** *Cover waste rock with geofabric, clay, topsoil, and then vegetate*

6. Recommended Rehabilitation Alternative

In the previous sections, comprehensive remediation alternatives were developed, evaluation criteria were identified and the remediation alternatives were evaluated with respect to these criteria and site-specific conditions. The recommended alternative was based on reducing infiltration through the surface of the Mine Area and treatment of groundwater pumped from the Tuttle Shaft.

6.1 Key Components of the Recommended Alternative

The recommended alternative for meeting closure objectives is to increase pumping from Tuttle Shaft; cover waste rock with geofabric, clay, topsoil, and then vegetate; excavate selected concentrated waste areas, fill excavations, then vegetate; cover selected heavily impacted soil areas with armour rock (enhancement), geofabric, clay, topsoil, and then vegetate (Main Mine Area); cover waste rock with geofabric, clay, topsoil, and then vegetate (Remote Mine Area).

6.1.1 Site Preparation

Prior to commencing the remedial work, site preparation work will be completed including mobilization of equipment (excavators, trucks, site trailers and other equipment), construction of access roads and establishment of temporary services.

Vegetation and trees of various sizes and maturity cover certain portions of this area. Works in this area will require the clearing and grubbing of the local flora. Clearing and grubbing would be kept to a minimum to preserve the natural condition of the site.

6.1.2 Tuttle Shaft Pumping System Upgrade

The current pumping system operates during low flow periods (dry periods) in the summer months. The pipeline is above ground and cannot be used in freezing temperatures in its current condition. Upgrades are required to increase the pumping of the deep groundwater at the Tuttle Shaft.

A new, more durable pump would be purchased and installed. Portions of the pipe would be buried to allow easier access to some areas. Heat tracing would be installed along with insulation to prevent pipe freeze-up during colder periods. The design of this system would need to be compatible with short- and long-term requirements in the Industrial Area. Furthermore, the ability of the current treatment plant to accommodate this additional load will need to be resolved.

6.1.3 Cover Waste Rock (Main and Remote Mine Areas)

Accumulations of waste rock from historical mine activities have been identified in both the Main and Remote Mine Areas. The preferred alternative would include isolating the waste rock from the surrounding environment to mitigate its leaching potential and to reduce the likelihood of human contact. The first step would see heavy machinery used to regrade the waste rock so that precipitation and runoff would be directed away from the waste rock. The regraded piles would be covered with a geofabric to prevent differential settlement and simplify the installation of cover materials. A clay material would then be used to cover the geofabric to act as a low permeability layer. The clay would be compacted to the necessary density to optimize the low permeability characteristics of this material. Vegetation and trees areas would be planted in a topsoil layer placed above the clay layer to blend with existing conditions adjacent to the affected area.

6.1.4 Removal of Greenish Powder and Arsenic Dump Materials

Materials with a high solubility potential were identified in the Main Mine Area. To mitigate the potential of leachate from these materials migrating and having offsite impacts, they would be excavated and consolidated with other highly soluble materials and stored onsite under more secure conditions (potential locations being the Industrial Area or the Tailings Area).

The remaining excavation would be backfilled with appropriate readily available "clean" material and compacted to the necessary densities to mitigate differential settlement potential. The fill would be covered with an engineered soil cover (described below) less the armour rock since the remaining soils may contain some low level residual materials.

6.1.5 Engineered Armour Rock/Soil Cover

The preferred choice of cover for the identified impacted soils in the Mine Area consists of layers of topsoil and compacted clay materials. These materials can be underlain by an armour rock layer that consists of large diameter rock that serve to discourage the excavation of the areas at some future date by a third party unaware of the conditions at the site. The confining layers and the armour rock are separated by a geofabric that mitigates the potential for differential settlement to the void space between the armour rock.

The topsoil provides the initial rooting medium for the cover vegetation, as well as some water storage capacity that will increase the effectiveness of the vegetation. The compacted clay layer functions as a restricting layer to minimize percolation of water into the underlying materials. Further design effort, material availability, quality and cost will determine the materials of construction and their sources.

6.2 Operation and Maintenance Requirements

Operating, maintenance, and monitoring efforts under the recommended alternative will be associated primarily with the Tuttle Shaft pumping system, vegetated cover maintenance (grass mowing in the first three years, watering of trees and/or shrubs, and tree replacement and culling) and monitoring the water quality of the Moira River upstream and downstream of the Mine Area. A detailed operations and maintenance plan should be established for the Mine Area following implementation of the recommended alternative.

6.3 Cost Opinion

A breakdown of the estimated costs associated with the recommended alternative is provided in Appendix B and is summarized below in Table 6.1. The costing in Appendix B has been completed at the conceptual design level and should be considered as a "cost opinion" to assist in selecting a preferred alternative. Costs can be further defined, once the preferred remediation alternative has been selected and a detailed design and approach is developed.

The net present value costs presented below are the sum of the capital cost and the net present value of the operation and maintenance costs. The annual operation and maintenance costs have been transformed to a net present value assuming an effective interest rate of 5 percent and a planning horizon of 20 years. The effective interest rate includes inflationary effects. It should be noted that operation and maintenance effort and costs will be required beyond the 20 year horizon. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

TABLE 6.1
ESTIMATED COSTS FOR IMPLEMENTING RECOMMENDED ALTERNATIVE

Cost Item	Estimated Cost
Capital Cost Items	
1. Site Preparation	$67,000
2. Tuttle Shaft Pumping Upgrade	$38,000
3. Main Mine Area Efforts	$428,000
4. Remote Mine Area	$69,000
5. Overhead, Insurance and Bonds	$58,000
Total Capital Costs	**$660,000**
Operation and Maintenance Cost Items (Annual)	
1. Pumping Operations	$2,100
2. Maintenance Operations	$8,400
Total Annual O&M Costs	**$10,500**
Net Present Value O&M Costs	**$140,000**
Net Present Value of Capital and O&M Costs	**$800,000**

As shown above, the estimated capital cost for the preferred alternative is $660,000 with annual operation and maintenance costs of $10,500 (net present value of $140,000), for a total of $800,000.

6.4 Data Gaps

A large pool in the Moira River, located immediately to the east of the Tuttle Shaft, was identified as a potential sediment trap which could be acting as an arsenic source for this section of the river (SRK, 1998). To assess the concentration of metals in the substrate of the pool as well as upstream and downstream of the Tuttle Shaft, CH2M HILL collected bottom sediment samples in August 1998. All results of the sediment sampling program are discussed in a report entitled *Technical Memorandum - Moira River Sediment Survey* (CH2M HILL, March 2001).

The findings of the above work are preliminary. A much more extensive study of sediments downstream of Deloro was completed in the Moira River Study (Golder, 2001). This study concluded that, although present, the contaminated sediments did not appear to indicate an adverse impact. The significance of contaminated sediment in the Moira River at the Deloro site will be re-examined as part of an ecological risk assessment.

Confirmation of material availability and associated costs must be made for optimizing the design. This could include limiting the use of high-quality clay and the use of more low-cost materials.

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APPENDIX A

MOE EA CRITERIA

TABLE A.1

RELATIONSHIP BETWEEN DETAILED EVALUATION CRITERIA AND ENVIRONMENTAL ASSESSMENT SCREENING CRITERIA

Environmental Assessment Screening Criteria	Detailed Evaluation Criteria									
	Social Considerations						Natural Environment			
	Public Acceptance	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character of the Area	Risk to Workers	Geochemistry	Terrestrial Habitats	Floodplain	Fish Habitats
Affect air quality	x	x	x	x		x		x		
Affect water quality or quantity (ground or surface)									x	x
Affect species at risk or their habitat								x		x
Affect significant earth or life science features							x	x	x	x
Affect fish or other aquatic species, communities, or habitat									x	x
Include or use land subject to natural or human-made hazards										
Affect the recovery of a species under a special management program (e g elk restoration)										
Affect ecological integrity							x	x	x	x
Affect terrestrial wildlife or habitat, linkages or corridors (including movement of resident or migratory species)								x	x	
Affect natural vegetation and habitat through fragmentation								x	x	x
Affect permafrost										
Affect drainage, sedimentation or erosion									x	x
Release contaminants in soils, sediments	x	x	x	x		x	x			
Create excessive waste materials							x			

Environmental Assessment Screening Criteria	Detailed Evaluation Criteria									
	Social Considerations						Natural Environment			
	Public Acceptance	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character of the Area	Risk to Workers	Geochemistry	Terrestrial Habitats	Floodplain	Fish Habitats
Affect areas of natural and scientific interest or provincially significant wetlands	x								x	x
Affect other (specify)										
Affect remoteness (access to inaccessible areas)										
Affect or obstruct navigation	x		x	x						
Affect other projects within a park or reserve										
Affect other projects outside a park or reserve	x	x	x	x	x					
Affect traffic patterns	x		x							
Affect public or private recreation	x		x				x	x		
Commit a significant amount of a non-renewable resource (e.g. aggregates)								x		
Affect noise levels	x	x		x		x				
Affect views or aesthetics					x			x	x	
Be a precondition or justification for implementing another project										
Affect uses, persons or property outside park or reserve	x	x	x	x	x	x	x			
Affect other (specify)										
Affect cultural heritage or landscape features		x		x	x					
Displace people, businesses, institutions, or public facilities				x						
Affect community character, enjoyment of property, or local amenities	x		x	x				x	x	

Environmental Assessment Screening Criteria	Detailed Evaluation Criteria									
	Social Considerations						Natural Environment			
	Public Acceptance	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character of the Area	Risk to Workers	Geochemistry	Terrestrial Habitats	Floodplain	Fish Habitats
Increase demands on government services or infrastructure										
Affect public health and/or safety		x				x			x	
Affect local economies				x						
Affect local businesses				x						
Affect other (specify)										
Affect First Nation reserves or communities										
Affect spiritual, ceremonial or cultural sites										
Affect traditional land or resource uses, or affect economic activities										
Affect Aboriginal values										
Affect other (specify)										

APPENDIX B

DETAILED COST OPINION

APPENDIX B

Opinions of Probable Construction Cost

In providing opinions of probable cost, MOE understands that CH2M HILL has no control over the cost or availability of labour, equipment or materials, or over market conditions or the potential Contractor's method of pricing. CH2M HILL makes no warranty, express or implied, that the bids or the negotiated cost of the Work will not vary from the opinion of probable construction cost.

CH2M HILL has made efforts to acquire area specific rates for materials, labour, and equipment whenever possible. The suitability of said materials to the intended purposes were not verified and will need to be determined prior to any construction activities. Where a local source or supplier could not be identified, industry budgetary tools such as the R.S. Means Company Inc. costing guide were used to assign a typical value. Appropriate regional coefficients were applied where necessary to adjust the typical costs to address regional conditions.

Each specific area of interest has been examined as an independent project. Any possible synergies associated with co-execution of various areas were ignored. Prices provided include the federal Goods and Services Tax (GST).

Volumes and areas were determined using existing available information. No additional investigations were performed to confirm or refute the estimates. Some estimates such as potential water volumes were based on engineering experience from other similar projects. Probable construction costs were based on typical weather conditions and may require adjustments due to extreme conditions.

Certain construction costs such as overhead, insurance and various construction bonds will vary based on the potential Contractor. Financial strength, experience, and previous history all play a role in determining the rates that will be applied to a particular Contractor. These sums were determined as a percentage of the total costs based on industry averages.

Several of the options involve additional pumping to the arsenic treatment plant located in the Industrial Area. The application of a varied number of options over the four main areas will result in increases and decreases of the total treated water volume. At this conceptual stage it is difficult to determine whether there will be a net increase or decrease to the volume of water to be treated. Therefore, the operation and maintenance of the arsenic treatment plant has only been considered in the Industrial Area evaluation. Actual operation and maintenance costs over the last decade were used to develop a weighted-average and one standard deviation was added to this value in an effort to create a conservative estimate. Wastewater treatment considerations for all other areas were limited to collection and transmission to the equalization pond (i.e. equalization/storage basin).

Finally, a 15% contingency was added to the final cost before taxes, overhead, insurance, and bonds.

The net present value costs presented in the following cost breakdown are the sum of the capital cost and the net present value of the operation and maintenance costs. The annual operation and maintenance costs have been transformed to a net present value assuming an effective interest rate of 5 percent and a planning horizon of 20 years. The effective interest rate includes inflationary effects. It should be noted that operation and maintenance effort and costs will be required beyond the 20 year horizon. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

Breakdown of Major Cost Items
For the Comprehensive Remediation Alternatives

	Alternative 1 *Increased Pumping at Tuttle Shaft* *Main: Cover Entire Area* *Remote:Cover Waste Rock*	*Alternative 2* *Increased Pumping at Tuttle Shaft* *Main: Cover Only Impacted Areas* *Remote:Cover Waste Rock*	*Alternative 3* *Increased Pumping at Tuttle Shaft* *Main: Excavate, Fill, then Cover* *Remote:Cover Waste Rock*
A. Capital Costs			
1 Site preparation	$67,000	$67,000	$67,000
2 Tuttle Shaft Pumping Upgrade	$38,000	$38,000	$38,000
3 Main Mine Area Efforts	$757,000	$392,000	$792,000
4 Enhancements (armour rock)	$91,000	$36,000	$0
5 Remote Mine Area	$69,000	$69,000	$69,000
Sub-Total	$1,022,000	$602,000	$966,000
Overhead, Insurance and Bonds	$98,000	$58,000	$94,000
Total (Including Enhancements)	**$1,120,000**	**$660,000**	**$1,060,000**
Total (Excluding Enhancements)	**$1,029,000**	**$624,000**	**$1,060,000**
B. Annual Operation and Maintenance Costs			
Increased Pumping Operations			
Annual Operating Costs	$1,700	$1,700	$1,700
Pump Replacement (Annuity based on 10yr replacement)	$400	$400	$400
Maintenance			
Cover	$1,200	$1,200	$1,200
General	$6,000	$6,000	$6,000
Contingency	$1,200	$1,200	$1,200
Total	$10,500	$10,500	$10,500
Net Present Value of Annual O&M Costs (20-year period)	**$140,000**	**$140,000**	**$140,000**
C. Net Present Value Capital and O&M Costs			
NPV of Capital and O&M Costs (Incl. Enhancements)	**$1,260,000**	**$800,000**	**$1,200,000**
NPV of Capital and O&M Costs (Excl. Enhancements)	**$1,169,000**	**$764,000**	**$1,200,000**

All costs include GST and a 15% contingency (before taxes, overhead, insurance and bonds)